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Understanding Acting in Complex Environments: Building a Synergy of Cultural-Historical Activity Theory, Peirce, and Ecofunctionalism

Leena Norros

University of Helsinki, Finland

ABSTRACT

A method of activity analysis is proposed that exploits synergy among cultural-historical activity theory, Peircean sign theory, and ecofunctionalism in response to challenges of modern work. The method comprises an operationalisation of the object of activity via the concept of core task, which enables contextual description of actions. On this basis, a semiotic analysis can be accomplished that reveals generic habitual ways of acting. The variation found in their interpretive strength for comprehending situations predicts differences in the mastery of work and learning in work. The method also allows definition of systems usability as a holistic quality-linked concept for purposes of artefact design.

Introduction

There is a pressing need to improve understanding of human activity in dealing with technologically mediated complex work. Although automation of industrial processes may increase the efficiency and safety of operations, intelligent human activity is still irreplaceable in securing operations and in managing the unexpected. Augmenting of the everyday environment with digital elements (as with the Internet of Things or augmented reality; E. A. Lee, 2008) enables the environment to act autonomously, which imposes challenges related to actors' expectations as to the regularities of the environment.

The knowledge and experience gathered so far by scholars of human factors and ergonomics provide a significant knowledge base and tested practices for facing the new challenges of work and everyday activity. However, the design of manageable and sustainable technologically advanced environments creates pressure for further development of the human-factors discipline. These increasing demands have recently been discussed in important fora of the human-factors community (Dul et al., 2012; Wilson & Carayon, 2014). In this discussion, fuller elaboration on our conceptions of human activity has been called for.

In this article I present my proposal for improving human-factors theory and methods.¹ I describe an activity analysis method and flesh out its deeper conceptual grounding. This method is aimed at improving understanding of the systemic content of activity and, hence, enabling comprehension of not only what people do, but also on which bases they act. I thereby address the generalised meaning of acting. Capturing the meaning of acting is important for deepening the actors' understanding of the complex phenomena of their work and for developing work.

The method requires theory that conceives of human acting as interaction with the natural and social environment, and that expresses interest in the processes of human meaning-making. Cultural-historical activity theory (CHAT), pioneered by L.S. Vygotsky, is such a framework, but

CONTACT Leena Norros  Leena.Norros@elisanet.fi  Fredrikinkatu, 73 B 19, 00100, Helsinki, Finland.

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can be usefully complemented by an ecofunctional perspective on activity (Del Río & Álvarez, 2007). This concretises the description of the environment by enabling comprehension of the possibilities the natural environment offers for acting. Further, for identification of the generalised meaningful patterns of acting, I turn to the theory of signs developed by Charles Sanders Peirce, which offers a model for demonstrating how meaning is communicated in action. By bringing together these three traditions' conceptions of human activity to construct an operative tool for the analysis of activity, I offer a means to yield greater insight into activity and more effective development of activity than could be gained via application of these theories individually. In other words, I offer a method that exploits synergy among the theories, but does not claim it to be a synthesis of them.

This article aims to argue for the acceptability of combining elements of the three component theories, to present the analysis method that the combination enables, and to discuss its practical benefits. To this end, first the following section identifies the shared epistemic and ontological basis of the aforementioned theories in philosophical naturalism. The philosophical relatedness of the theories is manifested in two key notions pertaining to activity—object-oriented activity and mediated activity—and is evident from the international research that has dealt with the conceptual relationships among CHAT, Peirce's work, and ecofunctionalism. In *Operationalizing meaning in acting* and *Operationalizing the role of tools in acting*, I describe the relevance of the notions of object-orientation and mediation of activity for understanding of problems of modern work and present the synergetic analysis method as means to tackle these problems. Finally, in *Conclusions*, I discuss the advantages of combining the three theories and show how this combining enabled the emergence of the novel concepts of core task, interpretive way of acting, and systems usability.

The methodological basis for synergetic construction of the activity analysis method

My attempt to construct a new activity analysis method is born of an urge to bring certain theories into interaction with one another with the aim of improving comprehension of the real-life phenomena related to complex work activity. In this respect, my way of constructing my method may be likened to what Davide Nicolini (2013) characterised as a “tool-kit approach,” that is, the theories featuring in the method or model have a family relationship, allowing a network of dissimilarities and similarities, but not necessarily entailing an inherent common feature that they all share (p. 214). Whatever their “ancestry,” it is necessary that the theories to be brought together have some shared fundamental understanding as to the nature of the relevant phenomena and about achieving knowledge of them. That is, they must demonstrate sufficient ontological and epistemological similarity, because the intention is to enable communication among the theories for increased understanding.

Connections to philosophical naturalism

The intention with this subsection of the article is to show that CHAT, Peircean theory, and ecofunctionalism possess shared methodological roots in the line of thinking called philosophical naturalism. I begin with a brief summary of the key assumptions of philosophical naturalism. Here, I draw on a recent account on naturalism as the philosophical orientation for a pragmatist conception of action (Määttänen, 2015).

Philosophical naturalism is a position from which nature is seen as a unified whole, encompassing also the human being and culture. All phenomena in nature obey causal order, and the phenomena can be subjected to empirical enquiry. Naturalism is typically associated with W.V.O. Quine's (1969) philosophical ideas linked to natural science, in which causality is conceived of as forward-directed reasoning from causes to effects. The proponents of American pragmatism criticised this notion of causality as too narrow and developed a form of naturalism that has been called soft naturalism. It accepts the causality characterising reasoning in natural science, but emphasises that another kind of

causality too needs to be acknowledged: anticipation, according to which something in the future may influence the present. Anticipation deals with intentional causes.

An important element of philosophical naturalism is its rejection of the idea that reason is independent of experience, which would lead to assuming the possibility of an aprioristic conceptual analysis. Such a rationalistic view would run counter to the idea in naturalism that all powers of cognition have been developed within nature. The meaningfulness of words and concepts is connected with human practices and, hence, results from combinations of human capabilities to act with the possibilities the environment presents for maintaining and developing the interaction. It follows that the results of experience of the interaction with nature are not merely facts, but obtaining them also involves value for the actor (Määttänen, 2015, pp. x–xi).

Philosophical naturalism takes a monistic stance on the mind–body problem. This position means distancing oneself from the idea of an external world that is internally represented in the brain. The brain can be considered to be the organ of thinking, but it would be strange to state that it is the brain that thinks, just as it makes little sense to say that the legs run. From a naturalistic point of view there is no need to withdraw from the notion of mind but, rather, to consider it as a property of the organism environment interaction (Määttänen, 2015, p. 57).

How is philosophical naturalism manifested in the theories we are interested in? The advances in biology made in the wake of Charles Darwin’s theory of evolution inspired philosophical naturalism, with the evolutionary perspective on nature opening possibilities to assume that the development of a human being could be conceived of in the same philosophical frame of reference. The biologist Jakob von Uexküll proposed that the organism and the environment form a coherent functional unit with the objects of the environment for achieving joint outcomes (Uexküll & Kriszat, 1932). In psychology, Gestalt psychologists echoed the development in biology and created an understanding of the environment’s role in shaping human behaviour. Later, the founder of ecological psychology, James J. Gibson, adopted these ideas and formulated his theory of perception, central to which is the idea that the environment is comprehended by human actors directly as features that enable purposeful activity (i.e., as affordances) and that no internal representation needs to be assumed (Gibson, 1979). Understanding the development of biological organisms, the human being among them, as part of the natural world has been termed “ecofunctionalism” (Del Río & Álvarez, 2007).

The American pragmatists, chief among them Charles Sanders Peirce and John Dewey, were important developers of the ideas of philosophical naturalism and contributed particularly to extending its suitability to scientific enquiry and problem solving (Dewey, 1999; Peirce, 1935). The important contribution of pragmatism to a naturalistic notion of human conduct is the more sophisticated conception of experience. Accordingly, this notion is not restricted to the traditional conceptualisation: perceptions resulting from external effects on sense organs. Instead, it is taken to include transformative action directed toward the environment. Associative connections emerge between sensory items not only on account of their sequential order, but also because of the operative successfulness of motor actions connected to them by neural mechanisms. The associations are built-in mechanisms—in other words, habits—that enable anticipation of the results of actions in different situations and demonstrate intentional causes (Määttänen, 2015, pp. 2–4, 35–39).

There is motivation within current Peircean semiotics to find naturalistic foundations that enable adequate analysis of human conduct. Semiotician Paul Thibault (2004) wrote that there is an urgent need for a materialist ecosocial semiotics that is able to reconnect body–brain processes and interactions to both social and cultural practices. He explained that semiotic activity both originates in physical-material interactions and, at the same time, has material effects on the environment, including other individuals and their bodies. Meaning-making activity always has both a semiotic-discursive and a physical-material dimension (Thibault, 2004, Chapter 1.1). In his reasoning on the connections between different levels of activity Thibault drew on the work of Jay L. Lemke, who has, among other things, discussed the functioning of an ecosocial system from the standpoint of multiple temporal scales, interaction among which is seen as enabled through semiotic artefacts—books, buildings, and bodies (Lemke, 2000).

Although ecofunctionalism and Peirce's theory seem to have a clear connection to philosophical naturalism, can a naturalistic tendency be seen also in the thinking of Vygotsky? A good basis for finding such an affinity is that he was strongly influenced by Karl Marx's materialist philosophy, which emphasises the role of human transformative practice in the construction of knowledge and focuses on understanding the societal-historical determination of the development of human beings and culture (Van Der Veer, 2007; Wertsch, 1985). With this in mind, it is not surprising that David Bakhurst, in an analysis in which he seeks rationalistic tones in Vygotsky's thinking, still firmly states that Vygotsky is a thoroughgoing naturalist and, beyond doubt, admires science. Vygotsky took scientific explanations to have three distinguishing characteristics: they are naturalistic, in that they refer to only phenomena that are constituents of the natural world; second, they are causally oriented, explaining events by showing how they are necessitated by prior conditions; and third, they are systematic, in that their intelligibility depends on a background system of theoretical knowledge (Bakhurst, 2007, pp. 50–51). Anne Edwards (2007) drew corresponding conclusions as to Vygotsky's philosophical orientation (pp. 77–78).

It appears that, in addition, Vygotsky shared the pragmatists' expanded conception of naturalism. Vygotsky's conception of causation was not mechanistic, and he was consistently hostile to reductive modes of explanation. He claimed that diverse forms of causal interaction need to be admitted and open-minded strategies adopted to integrate the various elements in our conception of the world to reflect the unity of nature (Bakhurst, 2007, pp. 50–51).

Even though there appears to be a naturalistic current flowing beneath Vygotsky's thinking, this aspect has not received much attention from scholars of his work. For example, Pablo del Río and Amelia Álvarez have stated that, relative to the attention received by Vygotsky's revolutionary work at two other frontiers of psychology (viz., the evolutionary-historical and the identity frontier of socially distributed functional systems), the third ecological frontier has received scant attention (Del Río & Álvarez, 2007, pp. 259–260). These authors argue that Vygotsky's analysis of human development drew on the materialistic concepts prevalent in the biology, psychology, philosophy, and history work of his time. His generic-cultural perspective complements the ecofunctional concepts by making explicit how the idea of the functional cycle uniting the human organism and environment gains strength when the mediating role of signs and tools is taken into account. The authors conclude that it is essential that Vygotsky's conceptions related to ecological features be understood in both cultural and symbolic terms, as well as against the backdrop of the biological organism.

Shared notions of the nature of human activity

The shared philosophical roots of CHAT, Peircean theory, and ecofunctionalism in naturalism become evident with respect to two central notions related to activity: object-orientation and the mediated nature of activity.

Object-orientation of activity

The three theoretical approaches discussed in this article consider human beings to be organisms oriented toward certain elements in the natural environment that have potential to support the existence of the organism; through becoming objects of activity, these elements become meaningful.

In ecofunctionalism, to make an object in the environment meaningful, the organism needs to be able to grasp the environment by perceiving and affecting the environment simultaneously. As a result, the functional cycle between the organism and environment is formed, as is made explicit in the organism–environment system approach of Timo Järvillehto (1994, pp. 62–66, 1998), which refers back to, for example, von Uexküll's work. In ecofunctionalism, the object is viewed as both subjective, on account of its meaningfulness, and objective, because it is composed of parts of the objective environment.

Vygotsky's notion of object-orientation reflects a cultural ecofunctional view in which particular emphasis is placed on the human actors' cultural extension of their meaningful subjective

environment and of the possibilities for perception. Human beings extend their effect on the environment and learn new mediated ways to act and engage with new activity systems. The cultural nature of human conduct was emphasized by Vygotsky's student and collaborator A.N. Leont'ev, who developed the notion of object-oriented activity. Leont'ev sees activity as the societal unit of life of a physical and material subject (Leont'ev, 1978, p. 50). Through activity's sensibility, the human organism is capable of identifying in the environment regular patterns of features that denote elements important in life. These become objects in the outside world, and the focus of the human actor's activity (Kaptelinin & Nardi, 2012; Leontjew, 1973, pp. 37–39; Vygotsky, 1978, p. 33). In this frame, meaning is understood as acting that establishes the relationship between the human actor and the object (Leont'ev, 1978, Chapter 4.3). The idea of object-orientation finds expression in Leont'ev's conception of the hierarchical structure of activity. He identified the levels of activity, action, and operation (Leont'ev, 1978, Chapter 3.5): Activity is defined via the object of activity, which is the societal motive for the activity. In the emergence of division of labour during the historical development of work, activity was broken down into actions connected to the situationally relevant goals and, further, into condition-specific operations. The idea of object-orientation of activity distinguishes CHAT from many other sociocultural theories (Del Río & Álvarez, 2007, pp. 270–271; Stetsenko, 2005, p. 70; Valsiner & Rosa, 2007, p. 5).

Peirce developed the understanding of object-orientation by explaining, in his meaning relationship model (Figure 1), how meaning emerges to concretise the possibilities of the environmental objects for human actors. The actors are equipped with resources (developed in a natural- and cultural-historical process) to grasp these possibilities. According to the model, meanings are formed as the product of a continuous cycle between the human and the environment: A sign (or, more precisely, sign vehicle) is perceived to denote an object in the environment, the emergence of which connection is evidenced by an act of interpretation, an interpretant (Määttänen, 2009, p. 126; Peirce, 1998b). Peirce (1958) clarified the meaning relationship as follows:

But we may take a sign in so broad a sense that its interpretant is not a thought, but an action, or experience, or we may even so enlarge the meaning of sign that its interpretant is a mere quality of feeling. A Third is something that brings the First in relation to the Second. A sign is a sort of Third. It appears to me that the essential function of a sign is to render inefficient relations efficient—not to set them into action, but to establish a habit or general rule whereby they will act on occasion. (p. 389)

As becomes evident in the preceding citation, in the emergence of the meaning relationship a *habit*, that is, general rule to act, is formed. Peirce thereby demonstrates the very idea elaborated later, for example, by the philosopher Evald Ilyenkov that meaning is not a merely mental phenomenon, but instead it is objective in the sense that it involves activity (Ilyenkov, 2009, 2014).

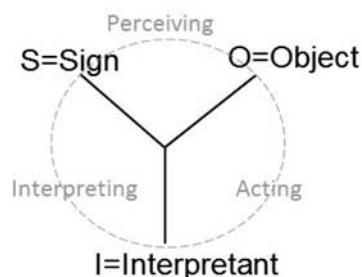


Figure 1. Peirce's meaning relationship model. *Note.* The continuous cycle of perceiving, acting, and interpreting, which produces habit (Määttänen, 2009, p. 126), is also depicted.

The mediated nature of activity

The second key activity-related notion shared by the theories under discussion here on the basis of their naturalistic orientation is that of the mediated nature of human action.

In ecofunctionalism, the concept of medium is a broad one, referring to the environment with which the organism is capable of forming joint functional systems. Del Río and Álvarez wrote that von Uexküll conceives of the medium as a system of specific media for each organism and of the organism as a component of various media. The authors went on to state that the organism acts upon the environment and actively contributes to its organisation, thereby shaping it for further development of the system (Del Río & Álvarez, 2007, pp. 266–270). A further idea in ecofunctionalism is that, although organisms act toward joint outcomes, a need for communication emerges, as does language to mediate acting in coordination (Järvilehto, 1994, pp. 100–101).

The conception of mediated action was developed by Vygotsky, according to whom human beings develop higher psychological functions by restructuring and reconfiguring their species-specific natural psychological functions. This restructuring is situated in the societal and cultural environment. Acting becomes mediated by external artefacts and signs that grow in number over time. With these aids, people can influence the environment, including themselves and others (Vygotsky, 1978). The mediated nature of action as an intrinsic feature of human conduct was elaborated comprehensively, for example, by James V. Wertsch (1998).

The meaning relationship model developed by Peirce manifests an assumption of a mediated structure of acting and thinking. Moreover, under Peirce's broad conception of the sign (see the preceding excerpt from his work), various qualities of signs, linguistic and nonlinguistic, can be assumed to convey meaning (Määttänen, 2015, pp. 42–43). A further feature of the meaning relationship model is that an interpretant can be taken as another sign, capable of inducing a new cycle of mediated acts. Hence, sign action (i.e., semiosis) would constitute an open-ended process (Bergman, 2009, pp. 117–118). Because semiosis is recursive, signs grow more and more intricate, and they become more removed from immediate experience. This is particularly true with regard to socially conventionalised symbols, such as those resulting from the use of language. Speech permits the creation of experiences quite remote from direct perceptual qualities (Rosa, 2007, p. 217). The multitude of types of sign opens one possible avenue for considering the multimodality of mediation that is inherent to real-world situations.

Peirce's semiotic model, by revealing how a real work environment becomes structured and meaningful for actors, became a means for augmenting the otherwise CHAT-driven approach in my empirical analysis. Susanne Bødker and Peter Bøgh Andersen expressed the same intention and combined Vygotsky's model and Peirce's in an operative tool. According to these authors the integration of Peirce's semiotic theory with Vygotsky's ideas was acceptable because the former enabled nonsemiotic, instrumental phenomena (Bødker & Andersen, 2005, p. 357).

The idea that Vygotsky's and Peirce's thoughts on mediation are mutually compatible in the analysis of activity finds support from James Ma, who proposes that synergy between the ideas of these two theoreticians could be a key for understanding multimodal mediation (Ma, 2014). Ma is concerned particularly about multimodality that extends beyond linguistic signs. At the outset in his discussion, he stated that, even though the mediating and transformative functions of signs are highlighted in both the cultural-historical theory of activity and sociolinguistics, both approaches underutilise the potential offered by Peirce's notion of the cyclical and generative properties of sign action. Accordingly, Ma (2014) grasped Peirce's idea that a particular interpretant linked to a specific individual's construal of a sign is itself an action in a particular situation. This enables the continuous process of semiosis (p. 375).

Ma acknowledges that M.A.K. Halliday's (1975) idea of culture as "offering the possibility of understanding the human mind in its interconnections with activity" (p. 283) resonates with CHAT and that said idea is supported also by Thibault's synthesis of "body–brain system, meaning-making activity, and the ecosocial environment in which the former are embedded" (Ma, 2014, p. 376; Thibault, 2004, p. 3). Hence, Ma concluded that there appears to be a conceptual shift under way

from the productive function of language to the agentive function of human action. Yet, he claimed, researchers have not been very specific in addressing the range of modalities where multimodality enters the picture, for example, the place of sound and gesture alongside language (Ma, 2014, p. 377). To fill this void, Ma proposed that, if feasible, synergy between Vygotsky's and Peirce's work could yield an analytical tool for understanding of multimodal mediation: "the mediational and transformative functions of signs, as advocated by Vygotsky, and the cyclical and generative properties of signs, as propounded by Peirce, that would coalesce to form a tour de force for multimodal analysis" (Ma, 2014, p. 378).

Operationalising meaning in acting

Comprehension of meaning for purposes of understanding the dynamic structuring of real-life acting was the goal behind the development of my analysis method. After first outlining this key practical problem, I turn to the conceptual structure of the method.

The practical problem: How to stay in the loop

The activity analysis method described here was originally targeted at process-control-type work. Such work is characterised by interaction with an autonomously continuing process or event. Typical examples are nuclear power plant control room work, or steering a large ship. The key demand imposed on the actors is to stay "in the loop." This means maintaining an awareness of the state and course of the process and acting in a situation-appropriate way in due time, that is, understanding what the situation means. Actors' mastery of this key skill was studied early on by human-factors experts, who at first exploited classical theories of decision making and judgment (see an overview, e.g., in Dowie & Elstein, 1988; Kahneman, Slovic, & Tversky, 1982). As a reaction against the normative nature of the classical theories, a new movement, labeled naturalistic decision making (NDM), then emerged (Klein, Orasanu, Calderwood, & Zsombok, 1993). In several joint monographs, proponents of NDM criticised the traditional approach of considering decision making in isolation from its actual context and detached from the real-world acting on the environment. Later, the concept of macrocognition was introduced to enable further distancing from the information-processing vocabulary of cognition (Schraagen, Militello, Omerod, & Lipshitz, 2008). Elaborated upon are macrocognitive functions (e.g., sense making or planning) and processes that support them (maintaining common ground and developing mental models; Schraagen, Klein, & Hoffman, 2008, p. 9).

I agree with the intentions behind NDM, but see the approach as not situated at sufficient methodological distance from the notion of cognition as something inside an individual's head when it defines phenomena related to decision making. This leads to considering the environment to be an external context for acting, not as a concrete part of acting that organises and directs activity as its object. This decreases the potential for NDM to address the logics according to which people make sense of the environment they are dealing with. In consequence, no basis remains for evaluating the appropriateness of certain activity apart from describing specific courses of action and evaluating them against an external reference for good acting, for example, outcome of the performance or its correctness with regard to a prescribed course. I wanted to allow for the option of addressing psychological phenomena in content-dependent terms for understanding the meaning of action as the basis of their evaluation. Grounding the method in philosophical naturalism enabled this.

The activity analysis frame

The soft-naturalistic orientation of the method constructed through combination of elements of the three theories is visible in its conceptual structure (see Figure 2). The structure is built on two dimensions that are necessary for comprehending human activity. The horizontal dimension in the illustrative figure represents the interaction between environment and organism. This is the natural

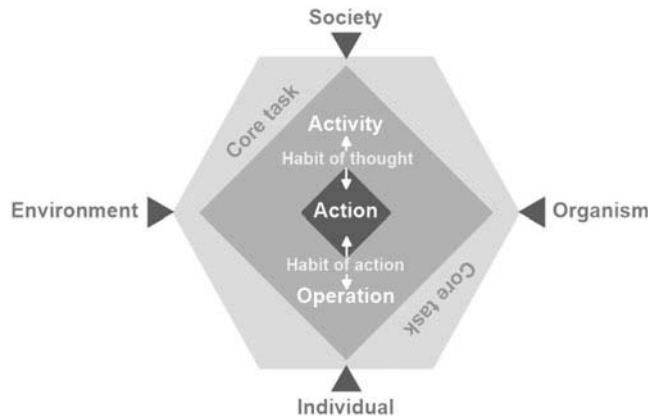


Figure 2. The frame for analysis of activity. *Note.* The analysis considers the interaction both between organism and environment and between individual and society (Norros et al., 2015, p. 23, Figure 2.3, with modifications).

dimension of activity. The vertical dimension is the interaction between the individual and society. This is the cultural dimension of activity. The conceptual structure of the activity analysis method extends across the field formed by these two dimensions. I can now elaborate on the analysis method with reference to the model presented in Figure 2.

Possibilities for acting

The natural and cultural dimensions delineate the work domain as that part of the environment that can potentially become the *object of activity*. This constitutes the first level addressed in the analysis of activity, and it is illustrated in Figure 2 by the light grey hexagon that forms the broadest area of intersection between the two dimensions.

The natural dimension of organism–environment interaction can be concretised by determining the environmental possibilities for action—affordances—(Gibson, 1977) and the species-specific and historically developed resources of the human actor to grasp them (adapted from Rabardel & Duvenci-Langa, 2002, p. 64). Both affordances and resources to exploit them are fundamentally interactive conceptions that describe the mutual dependency between the environment and the organism, but, respectively, express the relationship from the perspective of either the environment or the organism. A very similar idea of the organism–environment interaction is employed by Alberto Rosa (2007), who described interaction between the environmental affordances and the organism’s effectivities that results in a field of the potential for action and meaning (p. 220). In my analysis approach, a functional modelling technique developed by Jens Rasmussen (Naikar, 2013; Rasmussen, 1986; Vicente, 1999) is applied for examining the environmental possibilities. By this technique a multilevel abstraction hierarchy is constructed: The “purposes” of work are first identified. These are broken down stepwise so that next “abstract causal functions” relevant in the domain to reach the often contradictory purposes are identified. The causal functions are then broken down to “operative functions,” and these, again, to physical or social “components and mechanisms” to take care of the operative functions. Finally, material, temporal, and locational “forms” that the components or mechanisms consist of are identified. Such a modelling makes explicit the existing possibilities the actors may find significant to exploit while acting in the work domain. In contrast to most task analysis methods this technique describes field of possibilities to act, not prescribed sequences of actions, that is, it provides a map to navigate instead a route to follow.

The cultural dimension demonstrates the interplay of the individual and societal-historical processes and structures. To concretise this interplay, I exploit the activity-system model that Yrjö Engeström (1987) developed for cultural-historical analysis of activity and the work domain. In my use of this model the focus is on concrete understanding of the normative, instrumental, and organizational possibilities that the real work environment presents for action.

In my utilisation of the aforementioned frames to flesh out the two dimensions the work domain, again that part of the environment with potential to become the object of activity, is operationalised via the concept of the *core task* of an activity. I have defined the core task as “the generic key content that is relatively stable and unaffected by the current ways of accomplishing the activity, toward which core the activity should be oriented in order to be appropriate and develop” (Norros, Savioja, & Koskinen, 2015, p. 2). The core task is identified by means of a model including three generic characteristics of affordances. These include features that describe the dynamicity of the environment, the complexity of the relationships within its elements, and the uncertainty of the environment due to the contingencies of nature and the society, and the incompleteness of our knowledge of their phenomena. The model also involves three types of species-specific and historically developed resources that the human actor possesses to exploit the affordances. The resources involve skill-, knowledge-, and collaboration-related capabilities. A three-by-three grid is formed; these nine cells indicate different types of core-task demands (e.g., skills to cope with dynamicity, skills to cope with complexity, and skills to cope with uncertainty). The specific content of these core-task demands is derived from the results of the work domain modelling and activity system modelling and must be defined for each activity or work domain studied. (Norros et al., 2015, Section 2.2.2). Usually, the core-task demands express some inherent contradictions of the object that need to be balanced in activity. A recent example of use of the model in designing ship-bridge concepts is provided by Wahlström and colleagues (2016).

A further operative view of the object of activity is created by modelling the particular situations under scrutiny. A situation is considered to be an instance of the core task, in which its generic features are manifested in particular ways. The model used at this stage of analysis, called the *functional situation model*, articulates operative goals and tasks in relation to the functional objectives of the activity they fulfil. They demonstrate possibilities available for action in the specified situation (Norros et al., 2015; Savioja, Norros, & Salo, 2012).

Actual acting

Once the possibilities for acting in work have been considered, the process proceeds to scrutinising how these possibilities, along with ones not revealed by modelling, are exploited by the actors in reality. Vygotsky’s notion of tool-mediated *action* is hereby exploited. This level, the stuff of the second phase of analysis, is represented by the smaller, dark diamond in the middle in [Figure 2](#).

Data on actions are gathered by means of diverse observation methods, video or audio registration, self-reporting, action-tracing interviews conducted during online operation or referring to video recordings, or other interviews. A time-line description of the performance is then worked out. In construction of this description, the core-task model and situation models are used as a reference that supports detecting significant information on the progress of the action, people’s observations, various diagnoses and predictions, operations carried out, tools used, and so on, helping to ensure that, for example, these are properly identified and listed.

From the perspective on the Vygotskian notion of tool-mediated action, the analysis provides insight into the instrumental aspect of mediated action and may uncover aspects of the cognitive control of action: using the external tools as internally oriented signs. It is important to note that the information gathered at this level of analysis refers to individual actions of particular actors or teams, in the single situation under scrutiny.

Patterns of acting

Vygotsky's interest was not limited to the instrumental object-directedness of individual actions. He also acknowledged the semiotic dimension of activity achieved via the psychological tools (signs), especially through language. Signs not only enable control of an individual's behaviour, but also mediate shared meaning, perhaps in a more implicit form, and hence serve a communicative function too (Bakhurst, 2007, pp. 52–53; B. Lee, 1985, pp. 74–75; Vygotsky, 1978, Chapter 4; Wertsch, 2007, pp. 163–164). It is precisely this semiotic and communicative aspect of action that gives a generic meaning to the individual, situated actions.

Analysis of the generic meaning of acting in habitual patterns constitutes the third level in my analysis of acting. This is depicted in Figure 2 by the larger grey diamond. It illustrates how the unit of analysis is extended from action to activity through consideration of the levels in Leont'ev's hierarchy of activity. The meaning relationship model of Peirce is merged into the hierarchy to enable operationalising the connections between levels. Next I explain, first, how the sign model is used to describe habits and, second, how habits express the relations between the levels of activity.

When one applies the triadic notion of habit as meaning, operations that are defined as significant with regard to the core task can be considered to be interpretants (i.e., conditions under which a particular sign can be interpreted to refer to a particular object in the environment). In our empirical analysis, these meaning structures are referred to as *habits of action*. Differences in sign vehicles that trigger the same operation are identified, and their effective object is inferred on the basis of the understanding of the core task, and actors' accounts. It is also possible to observe differences in operations as responses to a particular sign vehicle and, again, infer the effective objects. By these means, based on empirical observations of the subjects' actual behaviour and on the conceptualisation of the core task, it is possible to identify different habits of action.

The meaning of acting in work was also studied via one-on-one interviews with people about their conceptions of their work. These conceptions are referred to as *habits of thought* (they were termed *work orientation* in earlier accounts), showing a conceptual epistemic attitude to the object of work. Various types of interviews for clarifying people's habits of thought as manifested in their work have been developed (Klemola & Norros, 1997; Norros, Liinasuo, & Savioja, 2014).

Upon observing people's actual behaviour and relating it to the conceptualisation of the core task, I am able to infer the actual effective objects in acting and how strong a tendency to generalisation with regard to the core task the situation-specific actions demonstrate. There I draw on Peirce, who saw interpretation as generalisation in the singular case (Peirce, 1998a). The semiotic interaction with the environment can be understood as a particular kind of reasoning: abduction. Characteristic of abduction is that guesses and assumptions about the environment are generated while one is acting. Abduction-based meaning-making enables an explanatory process of reasoning and can complement the (in principle) predictive deductive reasoning that Vygotsky's conception of the emergence of knowledge resembles—on account of his inclination to prefer rational justification of truth over empirical knowledge (Bakhurst, 2007, p. 41; Ma, 2014, p. 381; Vygotsky, 1978). Abductive reasoning is a generative process.

I refer to the tendency to connect the situational interpretation to a generalised understanding of the object (phenomenon) as an indication of *interpretive* habit. If the object instead is considered to reflect a preknown result from an established specific connection (fact) with a sign and an operation, I consider the habit to have a weaker tendency toward interpretation in the given situation. I label the habit *confirmative* in this case. Although less frequently, in some cases the object of activity appears to be reduced to acting immediately on the sign (feeling), showing a withdrawal from interpretation, rather than a tendency toward it. The habit in such a case is deemed *reactive*. Even though these differing epistemic attitudes in the construction of the object of activity in action appear to be partially tacit, they can, according to the sign theory subscribed to, be seen to reflect differences in the abductive strength of the reasoning. Hence, they can be expected to differ in their consequences with regard to resolving unexpected situations (Norros, 2004, pp. 210–211; Pettersen, 2013) and learning from experience (Norros, 2004, Sections 6.7 and 6.8).

The differentiation among habit types refers to Peirce (1958, 1977) and finds support from the work of Alberto Rosa. The latter drawing on Peirce clarifies several ways in which meaning emerges in action (Rosa, 2007, pp. 212–217): Rosa demonstrates first how an object in the environment becomes signified through various *phenomenological qualities* (basic forms of consciousness): Firstness, a mode of being of that which is such as it is, positively and without reference to anything else; Secondness, a mode of being of that which is such as it is, with respect to a second, but regardless of any third; and Thirdness, a mode of being of that which is such as it is, in bringing a second and third into relation to each other. The phenomenological qualities indicate different *relations that a thing can have with another thing*—a presenting, re-presenting, and interpreting relationship, respectively. Further, as Peirce held, things in consciousness may be related (in the aforementioned three ways) with objects having also any of three distinct *ontological statuses*: as a perceived possibility or feeling, verified existence or fact, or a regularity or phenomenon. When these two aspects of things being in consciousness (i.e., their phenomenological quality, and ontological status) and the three different possible relationships are taken into account, 27 logical possibilities emerge for how something can become a sign for something else. In keeping with a further assumption of the theory, only some of these possibilities can be realised for developing signs (Rosa, 2007, pp. 212–214). In my distinguishing among habit types, I focused on the differences in the *interpretive relationship*, within which it is the *ontological status* (feeling, fact, or phenomenon) that defines the differences. In my definition of the habit types I did not observe the presenting, or the re-presenting relationship (the latter involving the often mentioned icon, index, or symbol relationships). Support for my solution may be found in, for example, Bergman’s analysis of Peirce’s distinctions among types of interpretants and his statement on the role of the interpretative relationship when one is analysing meaning of habits (Bergman, 2009, pp. 108–116, 119–127). A recent account by Ma of the word-image complementarity in a semiotic process points to benefits of observing the aforementioned re-presenting relationship. His results indicate that identifying especially the interaction of iconic and symbolic representations would support analysis of the strength of abduction in action (Ma, 2016).

I can summarise that my typology identifying reactive, confirmative, and interpretive habits is a somewhat intuitive crystallisation of the complex sign theory of Peirce. The habit types express meaning through linguistic or nonlinguistic signs that reflect a more or a less developed interpretative relationship and consider differences in the ontological status of objects. The various signs are expressions of *generic patterns* of behaviour that the actors have appropriated as meaningful ways to act in certain situations. As they are optional reactions by real agents in real situations, they may also be seen as establishing the acting agents’ *personal sense* of the situation.

As indicated earlier, Leont’ev’s hierarchical notion of activity distinguishes among the levels activity, action, and operations. With the aim of analysing the relationships between action, activity, and operations, I draw on Leont’ev in seeing these relationships as orientation mechanisms that enable maintaining a connection to the object of activity, and to its societal meaning, in specific situations, that is, establishing their personal sense (Leont’ev, 1978, pp. 62–74, 89–90; Norros et al., 2015, pp. 32–34). As is evident from [Figure 2](#), depicting the activity analysis frame, *habits of thought* are considered the mediating element between action and activity. This element indicates maintaining orientation to the meaningful core task while accomplishing *goal-directed* actions under a certain division of labour. The orientation to the core task is maintained also in the operations, under particular *conditions*, whereby the meaning of operations is indicated by the element of *habit of action*. With both sorts of habit, the degree to which orientation to the meaningful core task is maintained is expressed in my distinction among reactive, confirmative, and interpretive habits, as previously described. In proposing analysis of orientation mechanisms by means of the sign model, I attempt to ensure that the analysis considers both the societal meaning and the psychological personal sense of actions.

Operationalising the role of tools in acting

In the highly complex and automated work the production processes are controlled collaboratively by a group of operators via information and control systems with extensive display-based human

interfaces placed in the main control rooms. Acting through this interface is the major medium for communication, but operators' verbal interactions, gestures, and spatial positions also serve communication. The analysis of activity should consider the use of these diverse media and their appropriateness in conveying meanings of the events in the work process, and in the control room.

The practical problem: Whether a particular tool is acceptable for use

Among the most challenging issues in the control of reliability and safety of the complex systems is that of ensuring the quality of the digital information and control systems. Human-factors knowledge has been successfully used in the validation of control rooms that are based on analogue technology, by such means as developing guidelines and standards, but these measures have been found insufficient for evaluation of computerised control rooms (O'Hara, 2014; Savioja, 2014). Within human-computer interaction research, typically dealing with everyday appliances and services, the challenges of the digitalisation of artefacts have been subject to study much longer. The discipline has offered theoretically and methodically significant results that allow understanding the tools in question from a more holistic perspective (Arvola, 2010; Bødker, 2006; Kuutti & Bannon, 2014). Drawing on activity theory, Rabardel and Beguin (2005) provided an important theoretical account on the mutual interaction on the development of activity and the role of tools. However, even further theoretical attention to determining the generic role of tools in activity is still needed for developing a firm foundation on which to develop understanding of what is a "good" tool.

The frame for determining the appropriateness of tools

A new notion of *Systems Usability* to indicate the quality of modern complex tools was developed by Paula Savioja (2014) and the present author. It exploits the idea of the multimodal mediation of activity. The notion was aimed to maintain sufficient concreteness with regard to the work domain and the demands it imposes. It also provides means by which the quality demands can be related to the purposes of the activity and to the generic domain inherent demands for acting appropriately. Beyond this, the definition of the quality for the tool must encompass also the various roles of the tool, that is, its generic functions need to be grasped.

The central idea in the definition of tool functions was to draw on Vygotsky's notion of tool-mediated activity: An external tool serves an *instrumental function* when affecting the object of activity. It also forms an internal tool enabling a *psychological function* for the control of activity. Both of these functions emerge on intersubjective bases, thereby enabling communication (Vygotsky, 1978, Chapter 4). From these premises we developed the notion of generic tool functions and abstracted three functions, *the instrumental*, *the psychological*, and *the communicative*, that all tools are supposed to fulfil. The grounds for separating out the communicative function lie in the semiotic model of Peirce and are consistent with Georg Rückriem's (2003, 2009) proposal to develop the communicative aspect of the Vygotskian notion of tool-mediation.

In the evaluation of technologies, it is commonplace to conduct performance-based assessments. The analyses typically focus on actions and operations, especially their measurable *performance outcomes* (performance time, accuracy, failure rate, etc.), and they are tied to the actual situation-specific usage of the tool. But anticipating its usage in the future necessitates a more generic perspective on the activity. In this connection, the analysis of *habits of action* and *habits of thought* for indicating the generic "way of acting" that a tool suggests was employed. Thereby, it was possible also to consider both linguistic and nonlinguistic expressions of meaning in action. Furthermore, the emotional aspects of activity were acknowledged. In particular, I can cite as rationale the positive emotional experience that re-mediation of activity by a new tool arouses in experts in the specific work involved (Koski-Jännes, 1999, pp. 439–441). Hence, *user experience* was included as a third aspect of activity to be analysed, for its potential to reveal the promise of the new tool.

The aforementioned reasoning led to the final concept of systems usability developed. In referring to systems usability we mean

the capability of the technology to fulfil the instrumental, psychological, and communicative functions of a tool in the activity and to support fulfilment of the core-task functions in the work. Systems usability is evidenced in technology's usage by an appropriate performance outcome, way of acting, and user experience. (Savioja, 2014, p. 87)

The systems usability concept was operationalised with the aid of the 3×3 systems-usability grid (see Figure 3). The grid identifies nine general indicators of systems usability (Savioja, 2014; Savioja & Norros, 2008).

The definition of the nine general systems usability (SU) indicators addresses the specific nature of each of the tool functions. Moreover, depending on the perspective to activity (performance outcome, way of acting, or user experience), each function is manifested in a different quality. In operationalisation of the indicators, specific criteria must be defined that reveal the strength with which the tool usage is oriented toward the core task of each concrete work domain. Hence, it is always necessary to develop domain-specific descriptions for the indicators. These can be used as high-level design requirements for new tools.

Conclusions

In creation of the activity analysis method, including the model assessing systems usability, the intention was to improve solving of problems in complex work. Theoretical and methodological work became necessary for reaching this goal. This led to the attempt to build a synergy between CHAT, Peirce's work, and the ecofunctional view of activity, as has been explained in the article.

The advantage gained from the combination of the theories comes, first, from the possibility of making the cultural and the natural determination of acting explicit in the method. The ecofunctional perspective was used to highlight the environment–organism interaction, on which basis the affordances and resources for acting could be defined in the operationalisation of the object of activity, determined also by the cultural dimension of activity. Both the natural and cultural dimensions are taken into account in the concept of core task that operationalises the object of

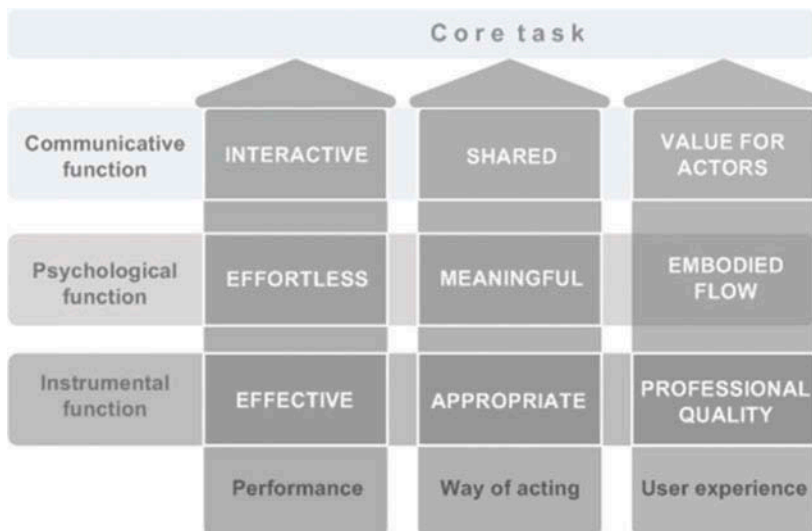


Figure 3. The general indicators of systems usability. *Note.* These emerge when the three tool functions are connected to the three perspectives on activity (Norros et al., 2015, p. 39).

activity. Synergy of the theories supported, second, the comprehending the meaning that is embodied in the operations of actors when they accomplish complex work. This advantage was gained by exploiting the sign model of Peirce for defining habits of action and habits of thought in a manner that enables identification of the internal dynamic connections in the hierarchically constructed activity, as defined by CHAT. The third synergetic effect is linked to the advantages for developing a theoretically coherent understanding of the complexity of the mediating role of tools in activity. The tools have multiple functions, as CHAT and Peirce's work attest, and the mediation is effected through conceptual and bodily means, as is confirmed by ecofunctionalism. The gains from combining the three theories become concrete in three new operational notions: These are *the core task*, *an interpretive way of acting*, and *systems usability*. All three represent an attempt to define cognitive phenomena in context-dependent terms.

The foundational concept for the method is that of the core task. It operationalises the notion of object of activity and provides a basis for a contextual analysis of activity. By using it, the psychological phenomena of work do not need to be treated in terms of notions referring to events in the actors' heads; instead, activity can be described via a vocabulary that refers in a content-dependent way to the interaction between the human organism and the environment. The notion supports involvement of the end users and subject-matter experts in the analysis of the work, and it offers a joint language for use by engineers and human-factors experts in the design of future work. Calls for such modelling and related attempts to model work domains have been made recently by researchers and developers of complex systems alike (Bennet & Flach, 2011; Naikar, 2013), though without a connection to cultural-historical activity theory. Further research is needed to better address the existing inherent contradictions in the modelling of the core task.

The concept of interpretive way of acting denotes a certain habitual quality of activity. Leont'ev's hierarchical structure of activity was elaborated by expressing in a concrete way the connections between the levels of activity. I have posited that maintaining orientation to the object of activity in actions and operations can be described with the Peircean semiotic concept of habit, expressed as habit of thought and habit of action. I identified differences among habits, which can be explained by differences in the abductive explanation-seeking tendency manifested in them. Interpretive acting refers to full abductive power and a strong tendency of generalising in particular situations and generating new knowledge in action. Further research, especially considering current ideas of semioticians interested in the potential of CHAT (e.g., Ma, 2014, 2016), would be needed for carrying the analysis of habits of action and thought further.

Interpretive way of acting is a potentially available mode in all activity, in all situations, yet, as we have shown in our empirical studies (Klemola & Norros, 2001; Norros et al., 2014; Norros et al., 2015; Norros, Savioja, Liinasuo, & Wahlström, 2014; Savioja, Norros, Salo, & Aaltonen, 2014), the possibility is not fully exploited, even by experts of their work. Rather, a confirmative tendency dominates, that is, the maintaining rests in the use of an established reaction, or a rule. This is fine in most cases and for doing one's duty, but, because an interpretive way of acting supports presence in repetitive yet still always specific situations of work, the variance in given situations may be revealed, with well-adapted responses and learning from experience resulting. Interpretiveness improves generic understanding of work, and it facilitates the agentive role of actors; they hence can discover new solutions when unexpected situations are encountered. The concept of interpretive way of acting has some resemblance to the concept of mindfulness as employed by Karl Weick and Kathleen Sutcliffe in their analysis of adaptive practices in organisations (Weick & Sutcliffe, 2007). Both concepts highlight phenomena that increase system resilience and the ultimate sustainability of the relevant systems. More insight would be needed as input to studying the relationship between interpretive and confirmative ways of acting in real-world situations.

The concept of systems usability refers to "good" quality of a tool or technology. Significant for the construction of this notion was to connect usability with the purpose of the tool in work, described in light of the core task. The complex and multimodal nature of mediation in activity

formed further theoretical grounds for the concept of systems usability. The value added by the systems-usability concept can be summarised in two points. First, it is important that the human-factors evaluations of tools can hence be linked to engineering definitions of the design requirements for tools. More detailed design and evaluation criteria can be developed jointly on its basis. Second, the concept can bring added value through presenting an opportunity for understanding the multimodality of mediation of modern environments. A practical design-relevant side to multimodality of mediation has been raised by Bødker and Andersen, with their statement that hiding technological functions of tools behind the interface of technical devices may pose an obstacle to understanding what the tools are doing (Bødker & Andersen, 2005).

The concepts of core task, interpretive way of acting, and systems usability were created quite recently. There is work to be done toward a better understanding of their theoretical underpinnings. Theoretical work is also needed for clarifying the practical potential of these concepts. Therefore, research is currently being conducted to elucidate the connections between promoting interpretive acting and using formative development methods based on Vygotsky's thoughts in work-based learning (Seppänen, Kloetzer, Riikonen, & Wahlström, 2016). Work is ongoing also on the implications of the systems-usability concept for understanding and developing trust in technology (Karvonen, 2017). We do not want to find ourselves in the situation predicted by McLuhan and McLuhan (1988), wherein, because people have difficulties in identifying the significance of media for activity, "man cannot trust himself when using his own artefacts" (p. 95).

Note

1. The analysis method was introduced in its earliest form under the label Core-Task Analysis (Norros, 2004), and a more advanced version was later embedded in a human-factors design approach, Core-Task Design (Norros et al., 2015). The work presenting it describes many practical problems of work in a number of complex safety-critical domains.

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