MAX-PLANCK-INSTITUT FÜR WISSENSCHAFTSGESCHICHTE
Max Planck Institute for the History of Science

2009

PREPRINT 375

Ludmila Hyman

Vygotsky on Scientific Observation

L.V. Hyman

Vygotsky on Scientific Observation

> "For me the primary question is the question of method, that is for me the question of truth…"
> — Vygotsky in a letter to Luria, March 5, 1926

Introduction

Psychology is an important resource for the study of scientific observation for at least two reasons. First, over the past century psychology has attained considerable knowledge of perception and other cognitive processes; this knowledge can help explain scientific observation as a psychological process. Second, psychology has been acutely sensitive to scientific observation as its own method. It is a science whose subject is "the most complicated of all things in the world and least accessible to investigation" (Vygotsky, 1982/1997, 328), and it has been in search of a better empirical methods since its inception (Fuchs & Milar, 2003; Mandler, 2007).

Scientific psychology begins with attempts at controlled observation of sensory and mental experience in the laboratories of Wundt, Ebbinghaus, G.E. Müller, G. Stanley Hall, Titchener, and others in the late nineteenth century. Methodological problems related to observation precipitated a "crisis" in psychology in the early twentieth century, which exposed the confrontation between objectivist approaches (such as the reflexology of Pavlov and Bechterev or the behaviorism of J.B. Watson) and subjectivist approaches (such as the introspective empirical psychology of the Würzburg school, the structural psychology of E.B. Titchener, and Dilthey's *verstehende Psychologie*). The "crisis" led ultimately to the rejection of the latter as a fruitful scientific approach but also gave birth to new attempts to reconsider the methods of psychological observation. Two novel programs of psychological research emerged: Jean Piaget's investigation of children's cognitive development by means of what he called "the clinical method," and L.S. Vygotsky's cultural-historical psychology, which introduced original techniques, based on the so-called "indirect method," of studying the higher cognitive functions. Vygotsky's approach was designed in part to counter the limitations of Piaget's.

In this paper I treat Vygotsky as a philosopher of scientific observation. I synthesize his ideas on scientific observation, demonstrate how he applied them in his research, and discuss some implications of these ideas for the history and philosophy of science. A caveat must be made that Vygotsky's empirical work in psychology was rather limited—largely as a result of his early death and political misfortunes. Yet he arrived at a methodologically refined understanding of scientific observation that was supported by his research into higher cognitive functions. This paper falls into two major parts. The first describes Vygotsky's perspective on scientific observation, while the second considers its applications and implications.

I. Vygotsky on Scientific Observation

The "indirect method"

In the 1920s, when psychologists were still debating the merits of introspection as opposed to objective empirical methods, Vygotsky reframed the question. He criticized direct observation as a method of scientific psychology and argued for the "indirect method"—that is, "the method of interpretation and reconstruction," which studies the object inaccessible to direct experience by its "traces" and "influences" in observable phenomena (1982/1997, 271). He argues that psychology should emancipate itself from the tradition of narrow empirical naturalism (such as description and classification of species in botany and zoology) and recognize its affinity with physics, geology, history, and philology. All of the latter disciplines study "what there is" (and in this sense they are "natural" sciences, as opposed to "formal" sciences, such as logic and mathematics), and all obtain their facts through methods that go beyond direct observation (Vygotsky, 1982/1997, 328).

According to Vygotsky, induction and mathematical thinking "substantially damaged" experimental psychology, because these methods were adopted mechanically and uncritically, as a result of psychologists' ambition to prove that theirs was a real science (1982/1997, 317, 269-270). The "blind importation" of empirical methods resulted from a naïve view of the natural sciences, which, in Vygotsky's opinion, are much less empirical than they seem.

Vygotsky refers to Max Planck, who declared the need to liberate physics from "the human eye." Planck (1919/1970) argued that since human vision had an extremely limited capacity to perceive electromagnetic radiation, scientific progress in electromagnetic theory depended on using "other perceiving and measuring instruments, such as, for example, the wave detector, the thermo-element, the bolometer, the radiometer, the photographic plate, the ionization chamber" (qtd. Vygotsky, 1982/1997, 271). It is the use of such instruments, according to Planck, that made possible "the unification of the whole system of theoretical physics," i.e. the creation of a more powerful explanatory framework (Vygotsky, 1982/1997, 271). Using an appropriate instrument allows the observer to isolate the essential qualities of the observed phenomenon and thereby separate "the basic physical concept from the specific sensory sensation" (Planck, 1919/1970, qtd. Vygotsky, 1982/1997, 271). More determinate concepts lead to more powerful theories of phenomena.

The other disciplines to which Vygotsky refers—namely, geology, history, and philology—resemble physics in that they do not have immediate access to their objects: history to past events, geology to the formation of terrestrial structures, and philology to ancient languages as living modes of expression. But practitioners of these sciences study these objects quite successfully by means of systematic analysis of "traces"—historical documents and artifacts in history, exposed structures in geology, texts and inscriptions in philology. Vygotsky emphasizes that historians do not study documents and artifacts for their own sake, but for the sake of reconstructing history *wie es eigentlich gewesen*. In a similar spirit, Nietzsche (1911/1964) insisted that the goal of philology was an understanding of ancient culture in its totality, rather than simply of ancient texts, which are preserved as *disiecta membra*.

As a result of indirect study, we can offer more powerful explanations of objects. "We do not share the ant's immediate experience of chemical beams" (an example from Engels), nor do we possess the immediate experience of the French revolution that an eye witness would have had, but "we know the nature of these beams better than ants do" and we have a better understanding of the French Revolution than would be possible without historical distance (Vygotsky, 1982/1997, 274, 271-272). Similarly, Vygotsky argues, we can acquire a better understanding of childhood than a child has.

Interpretation of "traces" in history, philology, and geology does not mean contemplative reflection, or undisciplined theorizing about the possible meaning of things, but rather the exhaustive collation of details through relational reasoning, responsible generalization and abstraction, and analogy. An interpretation of this sort may be wrong ("historians … are familiar with more than one erroneous construct based upon genuine documents which were falsely interpreted," 1982/1997, 272), but it is subject to correction by knowledgeable others. Thus Vygotsky takes an essentially reliabilist position that can be restated as follows: any specific claim can be wrong, but the method of knowledge production must be reliable (cf. Goldman, 1979; Swain, 1981). Vygotsky tries to clarify what constitutes this method for psychology and for science in general.

Psychology confronts a researcher with an array of objects that defy direct observation. These include all psychic phenomena that are neither expressed overtly nor registered by the subject, such as unconscious processes or developmental changes. Vygotsky stresses that we do not experience consciousness continuously, but only in fragments (1982/1997, 275). Yet psychology must account for the workings of mind and behavior as a whole. To achieve this end, psychology must devise effective interpretive methods that allow for the investigation of the invisible.

Vygotsky claims that the psychology of his time is confused about its goals: it "has too long striven for experience instead of knowledge" (1982/1997, 278). Instead of trying to understand psychological phenomena scientifically, it has tried to recreate them, either through direct observation (reflexologists, behaviorists) or through introspection (e.g. Wundt, Külpe, Vvedenskiy). This tendency has been reinforced by the "dogma" that "immediate experience … [is] the single source and natural boundary of scientific knowledge" (1982/1997, 272). Vygotsky counters with an opposing principle: "the whole point is that scientific knowledge and immediate perception do not coincide at all" (1982/1997, 271). Science is based on the premise that what we see differs from its essence, viz. our understanding of the essential qualities of the object in relation to other objects. The goal of science is to arrive at essences, rather than to register perceptions. Limiting inquiry to the directly observable not only excludes a wide range of significant objects, but also obscures connections. Scientific understanding necessitates the *explanation*, and not mere description, of objects (how they work, what causes them, how they function within a larger whole, how they will perform under certain conditions, etc.)—with the goal of making them practically manipulable, that is, for technological ends. Scientific understanding requires what Vygotsky calls "scientific concepts"—that is, well-defined mental constructs that contain models of abstract relations between entities.

Scientific concepts

Vygotsky distinguishes between "everyday" and "scientific" concepts (1982/1997, 281-291).[1] Both can be expressed in words, but they perform different intra-psychic and inter-psychic functions. Everyday concepts serve the purpose of communication in practical situations; they can refer to reality in a variety of nonsystematic ways (cf. Wittgenstein, 1953/2001). Scientific concepts are products of understanding reality on a higher level of abstraction (Vygotsky, 1982/1997, 249-253). Vygotsky stresses that scientific concepts do not replicate, or imagistically represent, portions of lived experience. Rather, they isolate and abstract salient features of an object. Unlike everyday concepts, scientific concepts possess a determinate structure, logical in nature (as in "classical" theories of concepts, such as the Aristotelian account, or frame-based theories, such as that of Barsalou, 1992). This structure arises from the analysis and synthesis of an object's salient features and places the object in relation to other objects. Scientific concepts are stipulated by definition and are systemic, that is, a concept is embedded in a network of concepts that is represented mentally or socially. Although scientific concepts necessarily posses an interpretive dimension, they refer back to nature (1982/1997, 248-249). Here Vygotsky relies on Engels' (1925/1978) view that even mathematical concepts, such as "infinity," capture some properties of the natural world. Vygotsky's position is that the formation of scientific concepts is "a complex and genuine act of thought," irreducible to other cognitive operations, such as reasoning (1934/1986, 149). This process deserves special attention as a basic component of scientific activity.

For Vygotsky, psychology faces a fundamental task—to build a system of scientific concepts and methods that will be specific to psychological research (rather than borrowed from

[1] "Everyday concepts" are, strictly speaking, pre-concepts, or "general representations" that treat objects as complexes. They are vague and only effective as long as they are used in situations. Vygotsky develops these ideas more fully in *Thought and Language* (1934/1986).

other disciplines). The first step in this direction consists in separating concepts from sensations. This separation, Vygotsky believes, "can take place only on the basis of the indirect method" (1982/1997, 274).

Tools: Concepts and instruments

In practical terms, psychology can study its objects "indirectly" through the use of *instruments* or through the use of *concepts* that guide experiments as well as both naturalistic and clinical observation. Both instruments and concepts can be considered tools.

Vygotsky insists on a radical similarity between the use of instruments in sciences such as physics, the interpretive methods of a historian or philologist, and the methods of psychological research (including tests, interviews, and coding schemes).[2] All have at their foundation conceptual constructs that isolate and reveal essential properties of the objects under investigation. Vygotsky dismisses the common misconception that physical instruments (such as "the microscope, telescope, [and] telephone") are "the extended organs of the researcher," which help him "see," rather than "interpret" (1982/1997, 273). The use of any measuring device involves an interpretation of visible indicators in order to assess an invisible process. Vygotsky considers "the use of a thermometer … [as] a perfect model of the indirect method" (1982/1997, 273). We read the temperature off the thermometer by interpreting "the rising of the mercury, [or] the expansion of the alcohol"—not by directly sensing heat or cold (1982/1997, 273). Thus we reconstruct temperature by means of its traces, relying on a previously established regularity ("the law of the extension of solids, liquids, and gases during heating") (1982/1997, 273). For

[2] Notably, psychologists themselves refer to such methods as "instruments": e.g., "coding schemes are measuring instruments just like rulers and thermometers" (Bakeman, 2005, 117). For examples of how coding schemes are used to analyze behavior see Parten (1932) and Bakeman & Gottman (1997). Methods of psychological research are a kind of instrument because "further refinement of the measuring instrument is always possible" (Bakeman, 2005, 118).

Vygotsky, “there is no fundamental difference whatsoever between the use of a thermometer on the one hand and interpretation in history, psychology, etc. on the other” (1982/1997, 273).

Knowledge production in the sciences involves a certain circularity. While methods and instruments depend on scientific concepts, the use of methods and instruments is indispensable for the formation and development of scientific concepts. The concept of “force” in mechanics genetically starts with “muscular sensation” (Planck, 1919/1970, qtd. Vygotsky, 1982/1997, 271). At that time the word “force” denotes an everyday concept, vague and situation-bound. It stands for a mental model (motion implies force; Renn & Damerow, 2007, 315-316) that comes to be erroneously extended in other situations. For example, Greek thinkers associated motion with force, assuming that in every instance of so-called “violent” (as opposed to “natural”) motion (e.g. an arrow in flight) a motive force must continually be present.[3] One such account supposed that a projectile was kept in motion via a process termed *antiperistasis*, in which the projectile displaced the medium (e.g. air), which in turn displaced the projectile, and so on, until the motion ultimately terminates (cf. Aristotle, *Physics*, 267a18 ff.).[4] Practical experience, including the use of instruments (especially artillery), led over time to a new understanding of “force,” which in the classical mechanics of Newton became a fully scientific concept (the time-derivative of momentum; $F=ma$).[5] We can compare the transformation of the term “behavior” in psychology. It starts as an experiential notion, but by being operationalized as an object of scientific inquiry it acquires a specialized meaning of “the sum of responses to environmental conditions” (Koffka,

---

[3] John Clement (1982) discovers similar beliefs among modern physics students who are first studying mechanics.
[4] Note that Aristotle rejects this account (Graham, 1998, 176).
[5] For this history, see Büttner et al. (2003); Damerow et al. (2004, 208-236); Renn and Damerow (2007, 319-323).

1924, 152). Consequently, the term “behavior” began to appear in novel and previously impossible collocations, such as “verbal behavior” (Skinner, 1957).[6]

Perception and cognition

Long before post-positivist philosophers of science (such as Kuhn, Hanson, Feyerabend, and Chalmers) proclaimed the absence of pure facts in science, Vygotsky argued this position from the standpoint of a psychologist. He insisted that neither in science nor in everyday life is there unmediated observation. Human perception works selectively in all circumstances, since “the whole mind is built like an instrument which selects and isolates certain aspects of phenomena” (1982/1997, 274). It follows that science is not a unique cognitive activity, with specific laws, but rather an extension of potentialities contained in everyday experience:

> Each organ takes the world *cum grano salis* – with a coefficient of specification, as Hegel says, [and] with an indication of the relation, where the quality of one object determines the intensity and character of the quantitative influence of another quality. For this reason there is a complete analogy between the selection of the eye and the further selection of the instrument: both are organs of selection (accomplish what we accomplish in the experiment). So that the fact that scientific knowledge transcends the boundaries of perception is rooted in the psychological essence of knowledge itself (1982/1997, 275).

The difference between everyday cognition and scientific cognition is the difference of degree. In everyday life we tend to experience the world as a “plenitude”—hence less differentiated, less governed by conscious selection and analysis. In science, by contrast, we intensify control at all levels of perception and cognition to obtain reliable results by manipulating particular objects. In both everyday and scientific practice we parse and categorize reality by means of language. The terms of everyday language already possess the potential for

---

[6] For the behaviorists (e.g. J. B. Watson, B.F. Skinner, E. C. Tolman, and C. L. Hull), “behavior” was the only proper object of psychological inquiry. The history of the term “behavior” and its meanings in psychology is instructive and deserves careful study.

expressing scientific knowledge (although in everyday speech they function in looser ways) (1982/1997, 249-250; cf. Sager, 1990). Scientific terms maximize this potential:

> Ultimately the scientific word aspires to become a mathematical sign, i.e. a pure term. After all, the mathematical formula is also a series of words, but words which have been very well defined and which are therefore conventional in the highest degree. This is why all knowledge is scientific insofar as it is mathematical (Kant). (1982/1997, 291)

Vygotsky insists that neither in everyday life nor in science can perception and cognition be separated (cf. Goldstone & Barsalou, 1998; Gregory, 1978).[7] We know invariably through "the activity of the eye … in combination with thinking" (1982/1997, 278). Vygotsky concludes that

> as methods for judging scientific truth, direct evidence and analogy are in principle completely identical. Both must be subjected to critical examination; both can deceive and tell the truth. The direct evidence that the sun turns around the earth deceives us; the analogy upon which spectral analysis is built, leads to the truth. (1982/1997, 275)

Methodology

The central question for psychology, just as for any other discipline, is how to produce correct interpretations of data. For Vygotsky the answer is *methodology*—a thorough design of the whole process of knowledge production. This design must employ theoretical analysis at each stage. There are three stages.

(1) Science starts with fundamental concepts—tentative models of essential relations between objects—that define what is to be investigated (1982/1997, 238-239, 249-250). In the process of investigation, these concepts are continuously revised when they are checked against empirical findings; new concepts are introduced to accommodate new discoveries (1982/1997, 253-254). Fundamental concepts are based on philosophical assumptions, concerning which the investigator must be maximally clear.

---

[7] Simon Kemp (1996) shows that in medieval Aristotelian theories of psychology, e.g. that of Avicenna (Ibn-Sina), there is a basic continuity between perception and cognitive activities such as imagination, cogitation, estimation, and memory formation and access (51-60).

(2) Fundamental concepts determine research methods, viz. techniques of obtaining data. Vygotsky highly values the experimental method in psychology. He is not concerned with the problem of ecological validity (the faithfulness of the experimental situation to the real world). Instead he argues that "the strength of the experiment is in artificiality" and stresses its affinity with theoretical analysis, which can be conceived of as a thought experiment (1982/1997, 320). In an experiment the investigator creates artificial conditions that allow him to isolate the essential properties of objects. He decides in advance how the given object represents a larger sample (e.g. Pavlov studies a particular dog's salivation to clarify the mechanism of conditioned reflexes in animals, 1982/1997, 318).[8]

(3) It is crucial for Vygotsky that the data obtained through experiment and other research methods are insufficient as a source of knowledge about mind and behavior. These data need to be interpreted to produce a plausible model, viz. a schema of abstracted relations that can be used to explain and manipulate the object. Vygotsky stresses that the mechanisms of interpreting data are of special importance: By what strategies of reasoning do scientists interpret their discoveries, i.e. build integrative accounts of objects?

Interpretation is analogical

Vygotsky maintains that interpretation in science works fundamentally by analogy (1982/1997, 277). The scientist must choose the right set of relations by which he can interpret the data analogically. Vygotsky's concept of analogy has its roots in the Greek term *analogia*, which always relates to a mathematical understanding of analogy in terms of two equal ratios; in other

[8] Similarly, behaviorists have noted that "the mathematization of response occurrences clearly denotes that we are fundamentally concerned with many similar response occurrences that constitute a distinguishable class of response. ... Obviously, it is response classes that interest us; and these classes are not directly observable but are inferred from certain types of referents" (Denny, 1986, 37).

words, *a:b :: c:d*.[9] Should mental phenomena, such as feelings and thoughts, be conceived by analogy with material entities?[10] Should the behavior of a normal adult be explained by analogy with that of animals, the child's cognition by analogy with that of an adult, ontogeny by analogy with phylogeny? Vygotsky paraphrases Koffka (1925), who argued that the structure of consciousness has to be conceived by analogy with the structure of behavior:

> There is no objective criterion for consciousness, we do not know whether an action has consciousness or not … . However, behavior is such that the consciousness belonging to it, if it exists at all, must have such and such a structure. Therefore behavior must be explained in the same way as consciousness. (1982/1997, 277)

Koffka (1924) argues against the behaviorists, who believed that the mind was a black box and could not be an object of scientific investigation. Vygotsky's and Koffka's thinking proved extremely productive in the 1970s and 1980s, when cognitive psychologists applied the principle of analogy between mind and behavior to the study of mental phenomena. For example, Shepard & Metzler (1971) definitively demonstrated that certain visually presented problems are solved by mental rotation. Their experimental procedure showed that the time needed to identify two drawings as different two-dimensional projections of the same three-dimensional object varied directly with the angle needed to rotate the two representations so that they are coincident.

---

[9] The term *analogia* is later transferred to other domains, particularly grammar, where it is used to establish relations between paradigmatic elements—e.g. Lat. *rex:regi :: lex:legi* (Taylor, 1977). Aristotle in *De memoria et reminiscentia* explains recollection (i.e. purposive search in a memory store) in such formal analogic terms (452b). The preeminent theorist of argumentation in the twentieth century, Chaim Perelman (1958/1969) transfers the mathematical notion of analogy to the domain of modern rhetoric; an analogy establishes a structural relationship between a *theme* (the target concept) and a *phoros* (the source concept).

[10] According to Koffka (1924), such a view led to "atomism" in psychology—that is, to conceiving of mental operations (feeling, thinking, perceiving, etc.) as essentially separable. Thus, for example, Titchener believes that the mind is composed of "sensations," "images," and "affections."

For an instance of this type of analogical explanation, note that D.O. Hebb (1955), at the prompting of B.F. Skinner, proposed a "conceptual nervous system" on the analogy of the physical nervous system.

Vygotsky had already asserted in 1926-1927 that such indirect experimental methodology was needed for serious scientific psychology.

Interpretation must be made explicit

Vygotsky's position can be summed up as follows: It is critical for science to bring the interpretive process to the fore—to make it an object of critical reflection and intersubjective evaluation.

If the process of interpretation is obscured, a sloppy interpretation emerges. Thus reflexologists denied the need to interpret the subject's physiological and behavioral responses (the visible) in relation to the realm of the mental (the invisible), yet asserted ungrounded, mentalistic notions, such as "the creative reflex" (Bekhterev) and "the reflexes of freedom and purpose" (Pavlov) (1982/1997, 276-277).[11] What is needed, Vygotsky believes, is to make the question of the relation between mind and behavior central to psychological research and to investigate this relation by means of appropriate concepts and methods (1926/1997).[12] Introspective "empirical" psychologists also fell back on interpretation—for example, when they took the words of the subject as direct evidence of his mental experience. But a psychologist must explain how the words themselves come to function as a response to internal and external stimuli (Vygotsky, 1926/1997).

Vygotsky insists that interpretation in science is inevitable, pervasive, and fruitful. It consists in positing the "connections, relations, sense, or function of the object in a larger whole."

---

[11] Similarly, the radical behaviorist Skinner in *Verbal Behavior* (1957) extends the concept of reinforcement, which had been rigorously employed in studies of animal behavior, in such a way that the term came to have what Noam Chomsky (1959), in his devastating review, called "a purely ritual function." Thus Skinner, for instance, claims that an author is "reinforced" in producing certain "textual behavior" by the (imagined) approbation of future readers (approbation which, after all, may never materialize).

[12] Kornilov and Luria tried to do just this (van der Veer & Valsiner, 1991; Cole, 2002).

These are never given to immediate perception, but are "found by inference" (1982/1997, 276). It is particularly important to foreground the process of interpretation in the human sciences. A human organism does not react to the world mechanistically, but selectively and purposefully; reaction and stimulus are *qualitatively* connected (1982/1997, 276). Psychology must problematize and elucidate this connection, and it can succeed only if it makes its interpretive procedures explicit.[13]

For Vygotsky, interpretation in science amounts to a systematic reflection on how knowledge is produced. It is in this sense that Vygotsky declares that "psychology must still create its thermometer": it "must develop its philosophy of equipment" (i.e. concepts, methods, and tools), which will specify *how* psychological knowledge is to be produced (1982/1997, 276). Crucially, the work of reflection has to be done *in* the sciences, in close proximity to the everyday

[13] Vygotsky (1934) analyses Piaget's early work as an instructive failure in this respect. He considers Piaget's "clinical method" highly productive, yet he criticizes Piaget's interpretation of his observations. Piaget (1924/1926) observed that children from three to eight exhibit a strong propensity for "egocentric speech"—speech directed to oneself, which serves as a seemingly useless (or so Piaget thought) "accompaniment" to action. Piaget conceived of speech as a reflection of the child's "tendencies" of thinking. He concluded that children possess only a weak capacity to adapt to another's point of view—a disposition he termed "cognitive egocentrism" (see e.g. 1924/1959, 37-43).

According to Vygotsky, Piaget's account is inadequate inasmuch as he does not reflect sufficiently on his own interpretive procedures. Piaget engages in excessive speculation—not just because his sample is too limited (this limitation is unavoidable with clinical observation, see Piaget, 1926/1929, 6), but mainly because he fails to analyze his findings deeply and critically. For example, Piaget assumes that in the child speech and intellect stand in the same relation to each other, and perform the same functions, as in the adult. Piaget does not explicitly express this assumption, and therefore obscures the false analogy upon which his reasoning rests.

Vygotsky believes that thought and intellect in the child are only *in statu nascendi* and therefore demand an independent investigation that does not rely on analogy with the adult. Vygotsky and his colleagues themselves conducted such an investigation in the early 1930s (1934/1986; Levina, 1968/2001). They revealed important functions of "egocentric speech" that Piaget had overlooked—the "reporting" and "regulative" functions of speech, which help the child organize its behavior and serve as a transitional stage between social and private ("inner") speech. Vygotsky (1934/1986) believes that Piaget's inadequate interpretation springs from his unclear philosophical and methodological premises; because Piaget refuses to adopt fully the position of either idealism or materialism, he is incapable of arriving at a rigorous conception of (psychological) causality and (consequentially) of psychological development.

routine of the laboratory—rather than in philosophy of science, which is a self-contained speculative field. Vygotsky clarifies this point in his polemic with the Kantian Binswanger (1922), who argued for a theoretical psychology as a formal study of concepts. Following Marx and Engels, Vygotsky insists that philosophy (of science) remains a fruitful enterprise only so long as it generalizes from, and reflects on, the actual knowledge attained in the sciences, i.e. advances scientific understanding at a higher level of abstraction (1982/1997, 291; 1928).

Vygotsky makes it clear that interpretation in science is not opposed to objectivity. Interpretation does not have to be an ideology—a closed system of beliefs resting on uncritical assumptions—but is part and parcel of the scientific process and is needed to get to the truth.

The indirect method in action

How is an indirect method to be designed in practice? As positive examples of the indirect method in use, Vygotsky considered the work of Köhler (1917), who developed ways of studying cognition in apes "without any introspection," and of Kornilov (1922), who used the dynamoscope to measure the energy spent by the subject when performing different cognitive operations (1982/1997, 278). Below I will briefly discuss how Vygotsky applied his ideas on the indirect method in his own research practice.[14]

Vygotsky and his colleagues designed techniques of data collection on the basis of a new theoretical paradigm—*cultural-historical theory,* which they developed from 1927-1928 on. In Vygotsky's account, cultural-historical theory focused on the formation of higher psychological functions, such as voluntary attention, categorical perception, logical memory, will, concept

[14] For various reasons, Vygotsky did not provide as extensive reports of his experimental methods and research results as we would expect from a psychologist of the present day (cf. van der Veer & Valsiner, 1991). Descriptions occur, for example, in: Vygotsky 1931/1997, 1931/1999; 1934/1986; Sakharov, 1928, 1930; Leontiev, 1931, 1932; Levina, 1968/2001; Shif, 1935.

formation, and reasoning. As opposed to lower (biological) functions, higher (cultural) functions develop through the mediation of cultural factors of three types: (1) material tools, (2) symbol systems (such as languages, mnemotechnical devices, writing systems, counting systems, numeric notations, algebraic notations, drawings, diagrams, maps, blueprints, artworks), and (3) the behavior of other people (Vygotsky, 1931/2006, 227; 1930/2006). Vygotsky understands such cultural factors as being essentially embedded in the context of the social organization of labor. Mastering external symbolic operations (originally means of social interaction) allows the child to master his own behavior. The child comes to recognize a sign "for others" as a sign "for oneself" and to use it in order to organize his own thoughts and actions (here Vygotsky follows Janet and is close to G.H. Mead; see Kozulin, 1991, 115-116, 329-322, 351-357; Vygotsky, 1989).

One of the primary tasks of cultural-historical psychology is to reveal how higher psychological functions develop in ontogenesis. Vygotsky and his colleagues attempted to demonstrate empirically how the child learns to use cultural signs (symbols) and tools as psychological instruments. Therefore Vygotsky often referred to his experimental approach as "the instrumental method." This term was intended to stress the difference between the traditional psychological experiment and Vygotsky's innovative technique. The traditional experiment attempted to reveal the connection between two entities: the stimulus and the reaction. Vygotsky hypothesized that higher psychological processes involved three entities: (1) the stimulus-object, or the target of action; (2) the stimulus-means, or a sign, which allows the subject to perform a cognitive operation upon the object; and (3) the reaction, or operation itself. For example, a knot on a handkerchief serves as a stimulus-means, allowing one to remember (reaction) that one has to buy bread (stimulus-object) (1931/2006, 278-280).

This idea led Vygotsky and his colleagues to develop the experimental technique of "double stimulation." Subjects were asked to perform a cognitive task that exceeded their natural capabilities. For example, they had to classify (reaction) a number of complex geometrical figures (stimuli-objects) with the help of other figures (stimuli-means) (Vygotsky, 1934/1986). In another study, children had to memorize (reaction) an extensive list of short utterances (stimuli-objects) by drawing pictures (stimuli-means) (Levina, 1968/2001). In a set of experiments inspired by Köhler, children had to get an object that lay beyond their physical reach by means of tools (Levina, 1968/2001).[15]

Vygotsky's technique was mixed. He used a loosely structured experimental situation as a framework for clinical observation[16] and pedagogical intervention. Stimuli-means were introduced into the situation gradually. Thus the experimenter could observe how the subject grapples with the task, failing to accomplish it naturally; how she searches for help; how she uses auxiliary means; and how she finally completes the task. Through the use of the clinical interview, the experimenter interacted with each child in unique ways in order to probe into her difficulties and dispositions. The experimenter also minutely observed the child's behavior. The goal was to perceive how the child constructs a meaning for the activity that is achieved in the experimental situation; this meaning, moreover, is interactional, in that it is necessarily related to

[15] The goal of these last experiments was to study the child's use of speech in the performance of practical tasks. Initially, Vygotsky (1934/1986) observed that the quantity of egocentric speech rises when the child is confronted with obstacles in performing a task. This observation led to a series of experiments that allowed Vygotsky to revise Piaget's conception of egocentric speech.

[16] Vygotsky's understanding of clinical observation is close to that of Piaget (1926/1929, pp. 2-10; see also Donaldson, 2005), who derives it from psychiatry and psychoanalysis. For Piaget, "the clinical method" consists in making the subject talk freely in order to elicit his genuine beliefs and dispositions. To produce this effect, the researcher must learn to avoid suggestion when interrogating the subject; at the same time, he must "constantly be alert for something definitive," i.e. develop working hypotheses that he uses to elicit the subject's responses (9). The key to interpreting the results of the clinical interview is a systematic analysis of the subject's utterances ("to keep every answer in its mental context," p. 9). According to Piaget, the art of clinical interview is learned under the supervision of a mentor for "at least a year of daily practice" (Donaldson, 2005, 108).

the experimenter (Levina, 1968/2001). For example, it was observed that the child's "egocentric speech" at the age of three to four served an important intellectual function that had been overlooked by Piaget: it allowed the child to create a reflection of its current stream of experience and to define the situation. It was observed that initially this reflection served a social function: the child addressed its "report" to the experimenter by establishing eye contact (Levina, 1968/2001, 84-85).[17] Studies of children from three to seven years of age revealed that "reporting" speech gradually takes on the "planning" function, allowing the child to organize its actions (Levina, 1968/2001).

When the child failed to use tools or symbols to accomplish the task, the experimenter would gently suggest ways of doing so. This procedure was seen as a condensation, or short-circuiting, of the longitudinal developmental process, giving cues to the child's prospective capabilities (in today's psychology this principle is used in "training studies"). Pedagogical intervention allowed Vygotsky and his colleagues to observe the potentialities of the child's development when it is aided by a cognitively more mature other. These observations became the basis for Vygotsky's concept of the zone of proximal development (see, e.g., 1934/2005).

Vygotsky believed that the technique of double stimulation (which combines experiment, clinical observation, and teaching) externalizes the process of *formation* of higher psychological functions. Therefore, he called his approach "genetic"—to emphasize its contrast with the static traditional experiment, which revealed a behavioral outcome (a completed reaction), rather than process aspects of behavior.[18] In externalizing internal activity through the use of auxiliary stimuli, Vygotsky (1931/2006) wrote,

> we are acting in the same way as, for instance, one who wanted to investigate the path which the fish follows in the depths, from the point where it sinks into water until it

[17] In current research on infants, psychologists study the infant mind by measuring visual fixations (see, e.g., the papers in Muir & Slater, 2000).

[18] We may note also that Piaget termed his work "genetic epistemology."

> comes up again to the surface. We envelop the fish with a string loop and try to reconstruct the curve of its path by watching the movement of that end of the string which we hold in our hands. In our experiments we shall at all times also hold the outer thread of the internal process in our hands. (1029)

The technique of double stimulation was used in studies of memory, choice, attention, arithmetic, and concept formation. These studies confirmed Vygotsky's idea that performing complex cognitive tasks requires the mediation of cultural symbols, they clarified mechanisms of symbol use in specific domains, and they greatly stimulated subsequent research in developmental psychology (Goswami, 2002; Fernyhough & Lloyd, 1998; Wertsch & Tulviste, 1992).

Vygotsky mainly concentrated on the level of analysis of individual cognitive operations by specific subjects (the "microgenetic" approach, see Werner, 1956; Granott & Parziale, 2002; Wertsch, 1985). He assumed that this kind of analysis sheds light on longtitudinal development.[19] To extend their data base, Vygotsky's team conducted cross-sectional studies of different groups of people: children of various ages (normal and abnormal), as well as normal and abnormal (aphasic, schizophrenic) adults.[20] For this reason Vygotsky called his approach "comparative." Vygotsky's results can in no way be considered definitive. Nevertheless, they continue to inspire research in developmental and cultural psychology, although recently particular aspects of Vygotsky's methodology have been called into question and modifications and extensions have been proposed (Lamb & Wozniak, 1990; van der Veer & Valsiner, 1991; Cole, 1995).

---

[19] Vygotsky recognized that the experimental analysis of cognitive processes, such as concept formation, was insufficient (it only reveals a "morphology of reasoning," but not its genetic development) (1934/1986, 145); we need also to account for "the facts of real development" in naturalistic settings (147). Shif's (1935) study of concept formation in the school setting constituted a step in this direction.

[20] On how Vygotsky used the results obtained in experiments on abnormal children and adults see, e.g., 1928/2006; 1931/2006; 1934/2006.

From observation to mediation: Tools and symbols in cognitive development and scientific activity

As an outcome of his studies, Vygotsky drew some conclusions concerning the role of symbols and material tools in cognitive development. Although he formulated most of these conclusions in the context of developmental psychology, they bear important implications for philosophy of science. If no unmediated observation exists, how are we to understand the processes of scientific observation and interpretation?

On Vygotsky's view, to study observation in science, one has to study how it is mediated by symbols (i.e. language used to express concepts) and tools. Scientific observation is the higher psychological process par excellence. Moreover, it is a kind of intersubjective cognition. Unlike everyday observation, scientific observation is disciplined by concepts and tools that make the process sharable and replicable. The better these concepts are articulated and these tools understood, the better people can assess, test, and improve them—and the more robust scientific knowledge will be. From Vygotsky's perspective, we need to account for, with maximal specificity, the role that tools and symbols play in scientific observation and interpretation. In this section, I summarize Vygotsky's cultural-historical account of how tools and symbols mediate cognitive processes. I discuss the implications of these ideas in the next section.

Vygotsky believes that both symbols and instruments play a role in cognitive development, but that the two play different roles (1930/2006; 1934/1986 on Köhler). Material instruments mediate actions directed at nature; symbols mediate one's own psychological processes as instruments of thought (Vygotsky, 1930/1960, 140). Yet the psychological aspects of instrument and symbol use are closely intertwined. Vygotsky was the first psychologist who studied the two as a unified system (1930/2006, 1052-1055).

Vygotsky maintains that language use restructures all psychological processes (perception, attention, memory, thinking, will, etc.). Speech first serves the ends of social interaction in the context of practical activity. Then it becomes internalized as an intra-psychic means of thought and self-regulation. As a result, human intellect becomes verbalized and speech intellectualized. Vygotsky was able to observe this process in his studies of "egocentric speech," which demonstrated that "planning speech" is a transitional stage in the development of the child's inner speech. Vygotsky's experiments showed that the child uses speech "as a stick," to organize a solution to a problem—first vocally then subvocally (1930/2006, 1067, 1071; 1934/1986).[21] "Planning speech" liberates one from the strictures of the "optical intellect," i.e. the intellect limited by the visual field, which is characteristic of apes (Köhler, 1917) and small children (Bühler, 1918; Vygotsky, 1930/2006; cf. the hypothesis of Armstrong et al. (1995) that speech developed in evolution to allow communication—which had been previously limited to the gestural modality—out of the line of sight).[22] Language creates cognitive distance between the immediate task and possibilities of its execution, or between the subject and her own psychological processes.[23] It opens up a space for reflection, enabling us to perform operations upon representations, and it makes possible novel forms of behavior (1930/2006, 1055, 1071).

Tool use (practical intellect) is mediated by language, since language provides scaffolding for thinking in general. On the other hand, more general thinking has to accommodate the

---

[21] Vygotsky and his colleagues observed that if the stream of speech is interrupted, the child often has difficulty performing a practical task (Levina, 1968/2001). In aphasics, practical and speech operations no longer work together (1930/2006, 1059).

[22] Experiments conducted by Vygotsky and his students demonstrated that children who were asked to plan their actions vocally reached beyond the situation in two ways: (a) they physically looked around, and (b) they thought about the possible course of action, by reverting to past experience (Levina, 1968/2001, 88). Vygotsky concluded that language creates psychological time: it sets the present against the past, and it stores present impressions for the future (Levina, 1968/2001, 84, 87-88; cf. Tomasello, 1999). Reflexive speech serves to store representations. Recent findings in the neurosciences indicate an association between spatial navigation, episodic memory, and action planning (Pastalkova et al., 2008).

[23] The same idea emerges from quite different source in J.G.A. Pocock (1973).

particular thinking about the tool use involved in the practical activity at hand. According to Vygotsky, we internalize cognitive operations involved in practical activity and transfer them to new cognitive domains (this idea was further developed by A.N. Leontiev, 1975; 2007, 49-53).

It follows that the use of tools is a powerful stimulus to intellectual development. Language makes it possible to use tools creatively—to invent and improve them by reflecting on how and for what purpose they are used, and how they can serve this purpose better (1930/2006, 1058). Reflective use of tools expands our cognitive habits. By using tools we change the structure of our behavior; we come to relate to the world as a world of practical action, which we can transform by means of appropriately designed instruments. It is in the nature of the human psyche, Vygotsky believes, that we apply this instrumental and practical attitude to ourselves. We learn to see ourselves as objects to be fashioned, and the world—as an increasingly richer repository of cultural means of self-fashioning (1930/2006, 1058-1059). It is in this sense that Vygotsky calls the human being *homo faber*: we not only make things, but also "*build* new organs" (higher psychological functions) through instrumental activity in the process of social life (1989; 1930/2006).

Vygotsky's argument prefigures a more recent argument. We know that the complete structure of the nervous system cannot be genetically determined, for the genes do not provide sufficient information for the future development of the brain.[24] The structure of the nervous system must to a large degree be determined by the interaction of the organism with the environment. At a certain point we create the environment, which affects our own neurological development. Nature grants us substantial freedom in what we become. Vygotsky is interested in

[24] The number of synapses in the CNS is on the order of 6×10^{14}, while the number of base nucleotide pairs (which represent information in the genome) is on the order of 10^9. It is unclear how much of the genome contributes to neurogenesis, and the specific contribution of learning and other environmental factors to the structure of the CNS also, of course, remains unclear at this time (Gierer, 1988).

what to do with this freedom. For him it is important that we use tools to further our own development.

As an example of a tool that can enhance our cognitive abilities, Leontiev (1974) discusses the computer:

> What functions do we relegate to the computer? All of the executive, operational part, which it does better than us anyway, because we think slowly (as in some eternal slumber). The machine also errs, but less frequently than us. It arms us, but the crucial thing is that as it arms us, it frees our thinking, and our thinking improves and thus creates new operations. And this process will continue to happen. They will only get smarter, these computers. And because they will always be progressing, we will also be getting smarter on this account. And we will creatively define new cognitive problems and find new cognitive solutions. There will be development. Do you think that this development is new? That it was discovered in the era of computers? No. It has always existed, yet before this computer technology it existed on a lower level than what we are capable of now. (345-346; translation mine—L.V.H.)

Leontiev emphasizes the inherent complexity of tools—their capacity not only to help us get a job done, but also to confront us with new cognitive challenges. The computer is one such highly complex tool that sadly often ends up being used merely as a typewriter. From the perspective of Vygotsky and Leontiev, to use the computer properly, one has (1) to know its possibilities and limitations; (2) to consider the nature of the work that we do with its help, our goals, methods, and procedures; and (3) to use the tool critically and innovatively to achieve our goals better (e.g. build software that supports more advanced research). In this process, we change as thinkers and scholars. We renovate ourselves by engaging with a tool.

Vygotsky and Leontiev lend a new meaning to the "instrumental attitude to the world." It is not an unthinking, aggressive attitude of consumption and transformation of the environment for one's ends, but self-transformation through a closer interaction with the environment. Unlike a nineteenth-century hero, who fashions the world in his image (cf. Hevly, 1996),[25] the hero of Vygotsky and Leontiev fashions himself in the image of the world. For the Soviet psychologists,

[25] For implications of "heroic science" see Milne (1998).

"pragmatism" is a higher form of humanism. We are in the world to cultivate both it and ourselves through concrete intelligence.

II. Implications

Clarifying the mechanisms of observation

If we follow the consequences of Vygotsky's ideas, we have to explain how observation is mediated by tools (instruments and concepts) in the work of particular scientific observers. Vygotsky's general approach needs to be rendered specific. What networks of concepts and what "philosophies of equipment" guide observations that leads to scientific discovery?

Vygotsky suggests that we study scientific observation as an intersubjective cognitive process. Our aim should be to reconstruct the cognitive mechanism whereby the scientist comes to identify the essential feature(s) of the object that he is observing. For Vygotsky, what matters most is not the act of observation itself, but the conceptual work that precedes and follows it.

To understand the scientific process, or any of its parts, one needs to analyze the comprehensive methodology at work—a complex architectonic of assumptions, principles, concepts, methods, interpretive strategies, and goals that guide knowledge production at all stages. The claim that science should be studied in terms of methodologies is by no means new. It has been repeatedly made by philosophers of science, who typically explore general epistemological principles of knowledge production. Yet a historian of science is left with practical questions: What kind of a system of propositions is a scientific methodology? How is it to be described? How does one begin to reconstruct it from a scientist's work? Vygotsky offers us answers to these questions. He suggests that a scientific methodology can be most effectively approached from two directions, both of which involve the reconstruction of a network of concepts. In the first approach, we focus on the tools of data collection and reconstruct the network of concepts that explicitly or implicitly governs the tools' use. In the second, we focus on the system of knowledge and reconstruct the network of concepts that scientists use to represent and produce this knowledge. The second approach demands that we focus on the meaning of scientific terminology: What are the central terms of inquiry? What conceptual content do they communicate? To what extent are they theory-laden? What work do they do, and to what ends?

The two approaches must be brought together. How are concepts that govern the use of tools related to concepts that govern the construction of knowledge? How are these concepts related to other components of a scientific methodology, such as philosophical assumptions and research goals? Both approaches allow for a systematic representation of a scientist's practice that extends beyond his epistemological commitments. We can understand how a scientist's practice functions as a concrete technology for producing scientific knowledge. Moreover, we can compare different scientific practices and methods and discover which aspects of these practices and methods are most productive.

Exploring new methods

Vygotsky understands science as an ultimately pragmatic enterprise. It must be flexible in its methods. Science is about results—i.e. attaining more robust and diversified knowledge, which allows us to manipulate the world more effectively. He calls for us to interrogate the tools of scientific inquiry—instruments and concepts—with a view toward improving them. The work of a historian who studies past uses of instruments is needed in the sciences, since such work can bolster the scientific creativity that drives research today. (It is for this reason that psychologists are so interested in the history of their own discipline: e.g. see Boring, 1929, 1942, 1950, 1963;

Watson, 1963, 1974, 1976, 1978; Wertheimer, 1970; Gardner, 1985; Kemp, 1996; Cole, 1996, 2002; Miller, 2003; Mandler, 2007).[26]

Vygotsky suggests that if we treat tools of psychological research creatively, as cognitive challenges that allow us to expand our range of thinking, we can radically enrich the repertoire of psychological methods. Since psychology deals with extremely complex phenomena, "its methods must be full of special contrivances and precautions" (1982/1997, 328). To create such "contrivances and precautions," Vygotsky pushed up against the limits of the classical experiment: he tried to combine the experimental method with the clinical interview and with pedagogical intervention. In his theoretical writings, he encouraged psychologists to develop even more daring methods. For example, he suggested the use of literature as an indirect source of knowledge about the cultural-historical psychology of concrete social groups (1989; 1968/1971).[27] His ideas on personality development suggest that psychology should strive to reach beyond the limits of the classical experimental paradigm. To study personal growth in naturalistic settings, the psychologist must enter into a genuine engagement with the subject (perhaps a long-term engagement), in which she both orchestrates and monitors an intervention (i.e. both creates and observes the zone of proximal development). This kind of practice can be compared to that of a parent who both observes and participates in his child's development.

Today's psychology is in many respects a fulfillment of Vygotsky's thinking about method. Alongside refined experimental techniques, psychologists have come to use a rich array of methods, including naturalistic studies, training studies, diary studies, computer simulation, neuro-imaging, and the study of historical texts (e.g. literature) as a source of psychological

[26] For reasons why it is the case see Hilgard et al. (1991, 100-101). Notably, these authors' understanding of the role of historical self-awareness in the development of psychology resonates with Vygotsky's.

[27] Compare the "literary anthropology" proposed by Poyatos (1988); and also the quite different approach employed by Iser (1993).

knowledge (e.g. Konstan, 2005). Cultural psychologists have been developing ever more advanced methods of studying cognition in live cultures (Cole & Scribner, 1974, 1981; Cole, 1995, 1996).

Psychology has become highly reflective about its methods.[28] George Mandler (2007) discusses problems of method in terms consonant with Vygotsky. He advocates supplementing experiment with "non-experimental scientific methods," looking for inspiration from the fields of astronomy and paleontology:

> Astronomers deal with objects—such as planets, stars, and galaxies—that are each unique and also follow general laws. These objects exist in aggregations that are characterized by the fact that the interactions among them determine in part the features and behaviors of the individual objects. Astronomers tend to find new objects that display characteristics not seen before, and they adjust their theories to take account of these new findings. To bring some structure into their endeavor, astronomers also survey the types of objects (such as stars) that they encounter, and such surveys establish typologies—categories of objects that have similar defining characteristics. There are no experiments in the sense of manipulating variables and observing their effects. The similarities between this kind of endeavor and a possible psychology of persons are obvious. (215)

Mandler discusses psychoanalytic theory as an example of "a 'psychoastronomical' endeavor," yet its limitations for him include the lack of a systematic "cumulative accretion of empirical knowledge and theoretical consistency" (216).

Paleontology (especially palebiology) combines "astronomical and historical methods" (216):

> Paleobiologists observe unique objects and relate them to general laws, but they also are sensitive to the contingencies involved in linear historical development. Development in the individual human is also contingent, and developmental psychology has—at times—concerned itself with such "longtitudinal" phenomena. What needs stressing more, however, is the way in which the unique individual is the cumulative product of historical process. (217)

[28] Although in the following discussion I concentrate on recent remarks of George Mandler, equally reflective proposals for psychological methodology—but ones that stem from a quite different perspective—may be found in Kagan (2006).

Like Vygotsky, Mandler advocates the importance of the developmental perspective in the study of all psychological phenomena; the attention to the individual, rather than to “average behavior”; and the relevance of psychology (and its methods) to everyday life (217-218). He discusses the rise of the new international psychology, which tries to expand psychological knowledge through cross-cultural research. For Mandler, the question of how to employ “astronomical” and “paleobiological” methods, especially in cross-cultural settings, remains one of the crucial challenges of contemporary psychology. From this perspective, the work of the Soviet psychologists, who had already arrived at similar questions, is of particular relevance today. Moreover, these psychologists offered methodological solutions to these questions, which have only been explored so far to a very limited degree; these solutions constitute a resource for, and a challenge to, contemporary psychology.

Understanding tools

Vygotsky’s work offers a new perspective on the tools of scientific observation. In psychology, these tools include protocols, photography, audio and video recordings; cards with images, Rorschach blots, blocks, and other sets of stimuli used as tests (such materials allow one to externalize some cognitive process); neuro-imaging and EEG; instruments to measure gaze (special contact lenses, cameras); instruments to measure sexual arousal (plethysmograph, pupillometer; see e.g. Lotringer, 1988); historically, the chronoscope and dynamoscope; and, increasingly, computers and their associated peripherals (which are not only used to present stimuli but also to measure and graph reaction time, heart rate, skin conductivity, etc.). Vygotsky insists that such tools are not distorting elements that intervene between the observer and the observed. Rather these tools make the invisible visible and thus allow one to observe and conceptualize a new psychological object. They isolate and abstract an essential feature of the psychological object, and thereby define the ideal object of scientific inquiry. Thus, for Vygotsky, tools are in effect prostheses of scientific cognition.

I.

Tools of scientific observation bring observation into the intersubjective realm. They create a representation of the object that makes it possible for scientists to reach agreement concerning what is observed. Vygotsky believes that no representation, including the image seen by the naked eye, is neutral, or objective; every representation is an interpretation. The goal of science is not to achieve absolute objectivity, but rather intersubjective agreement concerning (1) what is observed and (2) how to explain it (i.e. to create classifications, models, and theories of what is observed). Although both observation and explanation involve interpretation, it is useful to separate the two notionally, since they make use of different functions of scientific reasoning. For Vygotsky, it is crucial not to miss the first function—the definition of "what there is." [29] This definition is achieved intersubjectively by means of tools. Tools externalize representations of the observed and make it possible to perform cognitive operations upon representations—that is, to produce higher-order interpretations, or explanations, of the data.

Modern psychologists ensure intersubjective agreement about data by means of special procedures. These include the use of multiple coders to protocol directly observed behaviors or to classify experimental data, as well as data recordings (audio, video, digital, etc.). Thus multiple researchers can converge on the same observation. Intersubjective agreement is not infallible, for it may not of course correspond to the objective truth. But intersubjective agreement, despite its fallible nature, is the prerequisite for scientific knowledge.

---

[29] In texts, it corresponds to the rhetorical function of description. Vygotsky isolated and conceptualized this function as "reporting speech" in his studies of children's egocentric speech (1934/1986; Levina,1968/2001).

An example of how tools facilitate intersubjective cognition can be found in Philip Zimbardo's (2007) report of the (in)famous Stanford Prison Experiment. In August 1971 Zimbardo with a team of assistants conducted a mock prison experiment to study the psychology of prisoners. Two randomly selected groups of young males were assigned the roles of prisoners and guards. After six days the experiment was prematurely terminated owing to the unexpectedly escalating violence of the guards towards the prisoners. Zimbardo found the experiment so disturbing that he did not publish the full report of it until 2007, when he was provoked to analyze his 1971 findings by his experience in providing expert testimony for the defense of one of the Abu Ghraib prison guards. He was able to produce a report of the Stanford Prison Experiment on the basis of the audio and video tape recordings made in 1971. These recordings were examined and transcribed by Zimbardo and his assistants in order to determine the sequence of events that constituted the data. Through collective observation and evaluation Zimbardo and his assistants were able to, for example, reconstruct situations in which the guards displayed cruelty towards the prisoners and to determine whether this treatment was abusive.

There is no doubt that the work of observation performed by Zimbardo and his team was interpretive. But the resultant account was not merely that of a single idiosyncratic observer. A shared process of evaluation, in keeping with agreed upon scientific methods deemed reliable, allowed the researchers to evade the pitfalls of subjective interpretation. This point can better be understood by considering the fact that some of the evaluators, including Zimbardo himself, had been participants in the 1971 experiment, and their judgments as participants differed, sometimes sharply, from their later, more impartial, judgments, arrived at through a shared scientific procedure. For instance, Zimbardo, who had played the role of the prison superintendent, in retrospect realized that nearly all of his judgments of the experimental situation at the time had been distorted by his situational role. Through collective scientific observation Zimbardo's team produced an intersubjectively valid narrative of what happened (Zimbardo, 2007, 23-194), from which Zimbardo subsequently drew conclusions that can be generalized within the domain of social psychology.

This example illustrates how modern science solves the problem of collective observation. Whereas a representation of the data produced by one observer may be unreliable, several principled representations lend themselves to adjudication. Tools play a crucial role in this process because they allow for the externalization and sharing of representations.

II.

Vygotsky urges us to use scientific technologies for cognitive growth. He raises the following questions: What do tools allow us to do? How can we use them to think better?

Gigerenzer and Sturm (2007) have proposed that tools in science may perform a heuristic role in scientists' theory generation. For example, they argue that the use of the digital computer in psychological research in the 1960s gave rise to a new set of theories in which the mind was conceived of in terms of a "computer program" (306-307, 323-335). Gigerenzer and Sturm characterize the transfer of properties from tool to theory as metaphorical ("tools can provide metaphors that become concepts for psychological theories," 306). A theory informed by a metaphor (derived from a tool or some other source) can determine what data are collected and how they are collected (328-329). Theories determine knowledge, and the available tools serve as historically contingent resources for inventing theories. This view of science suggests that theories (conceptual models) are not inherently connected to the object of investigation, but may be superimposed on it through a leap of imagination. And it simplifies—obscures—processes of scientific reasoning.

Vygotsky offers a different perspective on the role of tools in the generation of theories. He views tools not as a source of metaphors—a mere heuristic for invention, based on a contingent similarity between two heterogeneous entities—but as material extensions of scientific thinking. A Vygotskian would emphasize that the history of the connection between computer and mind dates to the first half of the twentieth century, when the pioneers of the computer revolution started to develop mechanical and mathematical models of thought; in a seminal paper of 1936 Alan Turing developed a formal model of the "symbol-manipulating abilities of a human computer" (Norman, 2005, 301).[30] Reflection on computers and programming methodologies, which had themselves arisen in part out of reflection in human cognition, led to information-processing conceptions of particular mental processes, which focused on explicit modeling, such as Atkinson and Schiffrin's theory of memory (1968; modified and extended by Schiffrin and Schneider, 1977; and Schneider and Schiffrin, 1977), Schank and Abelson's (1977) theory of planning and organization of behavior, and Levelt's (1989) theory of speech production.[31] The

---

[30] Actually, this history could be extended back to Descartes and Julien Offray de La Mettrie, and should include Charles Babbage and others. In 1936 Turing was still considering the question of the way in which humans computed. He turned to the question of whether computers could think in 1950. For a collection of philosophical responses to Turing's 1950 paper see Shieber (2004).

[31] It should be emphasized that the history of the cognitive turn in psychology is much more than the history of the information processing model. At the same time that AI and computational modeling were becoming popular, a separate experimental psychology characterized by a cognitive perspective was developing, in a number of cases rather independently of contemporaneous developments in AI (see Greenwood, 1999; Leahey, 1992). American psychologists became interested in the work of certain British psychologists of a cognitive bent (Bartlett, 1932; Craik, 1943; Broadbent, 1958; Humphrey, 1948, 1951); in the developmental theory of Piaget and of Vygotsky (in part through the influence of Jerome Bruner); and in the more cognitively oriented behaviorism of D.O. Hebb (1949). Moreover, the Gestalt psychologists, who had emigrated to America, began to exert a noticeable influence (e.g. Köhler, 1929,1941; Wertheimer, 1945; and Duncker, 1926, 1935, 1945; see Katona, 1940). The Würzburg psychologist Otto Selz (1913, 1922, 1924, 1927), who had written extensively on the processes, rather than contents, of thinking, exerted, through his student de Groot (1946, 1964) considerable influence on the incipient computational approach of Newell, Shaw, and Simon (1958). The renegade behaviorist Karl Lashley, prompted in part by physiological concerns, authored one of the founding documents of the cognitive movement "The Problem of Serial Order in Behavior" (delivered at the Hixon symposium in 1948, published in 1951). In 1967 we

information processing model allowed for the first time an adequate explanation of many mental processes that had resisted explanation in the context of earlier paradigms, such as associationism. Information processing introduced an algorithmic approach that made it possible to connect lower-level and higher-level processes. By rigorously postulating mental processes inaccessible to introspection, information processing renewed interest in the unconscious and provided an integrative framework that unified both conscious and unconscious processes.

Information processing, moreover, allowed for an elegant integration of multiple empirical findings. For example, Levelt's (1989) model of speech production explains independent data from empirical studies of slips of the tongue, the "tip of the tongue" phenomenon, aphasiology, child language (L1) acquisition, and adult language (L2) learning. He adopts a principle of encapsulation (in which processes such as conceptualization, grammatical encoding, phonological encoding, and articulation are conceived of as maximally autonomous) not out of a commitment to abstract principles of information processing, but rather to explain patterns evident in empirical data (for example the specific distributions of performance errors). Details of human language processing continue to be debated by psycholinguists, but information processing models provide a framework in which an ever-increasing mass of data can be explained (see e.g. Jaeger, 2005).

The Vygotskian would point out that using information processing to model cognition is not based on a metaphorical transfer of meaning. The relevant kind of reasoning here is *abduction*—a concept specially designed to capture how an explanation (model) is inferred from facts (Peirce, *Lectures on Pragmatism*, *CP* 5.171, 2.777). "Metaphor" is inadequate to explain model building because (1) it is an inescapably linguistic concept (it involves a metaphorical use

find Ulric Niesser in his authoritative *Cognitive Psychology* explicitly dissociating recent progress in the psychology of perception, memory, and language from the AI and computer simulation movement (Greenwood, 1999, 18-19).

of a word, such as "pheromones send a *message*"); and (2) there is no reason to believe that processes of model construction in science need be linguistic.[32] Abduction works by analogy—a reasoning strategy that employs structural features of the source concept to conceive of the structure of the target. The computer provides a fruitful analogic model for the mind, because the two are sufficiently similar (one might note that cellular organelles are not explained in computational terms, despite the fact that molecular biologists frequently use computers). In science abduction serves to explain disparate bits of knowledge attained in a domain. Vygotsky stresses that there is no other way of building models (explanations, theories, hypotheses) than by analogy with other models. It is a responsibility of the scientist to choose analogies critically and to make this process explicit, so as to maximize agreement on the best analogy.

There is no need to suppose that scientists are unaware of the limitations of their models. If they were, they would not be continually revising them. For instance, in the 1980s connectionist models were developed to address some of the perceived limitations of traditional serially-oriented informational processing models (Rummelhart & McClelland, 1985). Historians of science need to analyze what benefits models bring to a scientific community—what kind of knowledge they allow scientists to produce and what this knowledge is good for. For example, Vygotsky's cultural-historical theory allowed him to explain cognition in relation to the symbol systems that constitute a culture. It made possible the development of techniques of teaching cultural knowledge to blind and deaf-mute children (*Collected Works*, 1997, vol. 2). Luria's conception of the brain in terms of "dynamic functional systems" allowed him to integrate the knowledge of neurological damage and that of the corresponding cognitive performance; on this basis, he pioneered techniques for the diagnosis and rehabilitation of victims of a traumatic brain injury (TBI) that remain of crucial importance today (Tupper, 1999). Newell and Simon's (1972)

---

[32] Also metaphor is a highly contested concept (cf. Ortony, 1979); to explain scientific model building through metaphor is to explain *obscura per obscuriora*.

work on problem solving has inspired various pedagogical approaches, such as the cognitive rhetoric of Flower and Hayes (1981; Flower, 1985, 1994). Cognitive psycholinguistics of the sort practiced by Levelt has applications in such practical areas as teaching of natural-sounding prosody to second-language learners of English (Wennerstrom, 2001).

In sum, our Vygotskian would say that information processing models of cognition are not just a fashion, based on unquestioned assumptions, but rather a productive way, learned (at least in part) from the computer, to think about cognition. The computer is not just a metaphor, imported into psychology, but a tool that allowed—and still allows—psychologists to think in new ways about human cognition. What produced information processing models of the mind was a powerful synergy of thinking *around* the computer, rather than starting *from* the computer. Let Newell, Shaw, and Simon speak for themselves:

> Our position is that the appropriate way to describe a piece of problem-solving behavior is in terms of a program: a specification of what the organism will do under varying environmental circumstances in terms of certain elementary information processes it is capable of performing. *This assertion has nothing to do—directly—with computers*. Such programs could be written (now that we have discovered how to do it) if computers had never existed. (Newell, Shaw, & Simon, 1958, p. 153; emphasis mine—L.V. H.)

Understanding language

Vygotsky advocates an instrumental approach to language. The symbols that comprise a language function as tools facilitating the transmission of knowledge and coordination of action in a community; they allow us to *do* things and are rooted in activities.

Vygotsky's psychological work suggests a rhetoric—an attitude to speech interpretation and production that emphasizes the effects of words. We should use language with a focus on what words allow us to achieve. This attitude is prominent in ancient rhetorical theory and literary criticism, as expressed by Aristotle, Horace, and Longinus, and exemplified by the orators of the Roman republic. In classical antiquity one studied texts to learn particular techniques from exemplars that could be adapted to one's purposes. In the words of Jane P. Tompkins (1980), for the ancients

> language is a form of power and the purpose of studying texts from the past is to acquire the skills that enable one to wield that power. … All modern criticism—whether response-oriented, psychological, structuralist, mythopoetic, thematic, or formalist—takes meaning to be the object of critical investigation, for unlike the ancients we equate language not with action but with signification. (203)

The attitude towards language as power—as an instrument that serves practical goals—is also prominent in today's sciences.[33] For example, psychologists have a concept of "construct validity," which forces them to exercise skepticism towards language in the process of research design. To claim construct validity, a researcher must argue that there is "a good match between a theoretical construct (e.g., aggression) and behavior measured in the experiment" (Lew, 2005, 120). This concept is of particular importance in developmental studies, when researches have to consider whether the behaviors that they study within the same framework and that they denote with a single word (e.g. affection) can in fact be equated: for example, mother-infant *affection,* as conceptualized by John Bowlby (1958, 1969) and Mary Ainsworth (Ainsworth & Bowlby, 1965; Ainsworth, 1978), and adult *affection,* as studied by Mary Main et al. (George, Kaplan, & Main, 1985, 1996) through the use of the Adult Attachment Interview (Lew, 2005, 121-122). For Vygotsky, the aspiration to verbal precision characteristic of experimental scientists is indispensable for any serious research in the sciences or in the humanities.[34]

Vygotsky made a notable contribution in demonstrating how language functions as a tool of thought. He was among the first psychologists to devote serious study to concept formation. Vygotsky challenges the common assumption that we think with words as the inalienable

---

[33] Pavlov fined people in his lab for using mentalist (rather than strictly behaviorist) language, since it affected the way people thought about their work (Vygotsky, 1982/1997, 287-288).
[34] Vygotsky paid great attention to language in his own writings, as we can observe from studying his notebooks and working papers (see now Zavershneva, 2008).

medium, or building blocks, of thought. We may compare some remarks of Jerome Kagan (2006) concerning non-verbal and even non-verbalizable elements of mental life:

> It is important to appreciate that meaning coherence applies to sentences or scenes and applies less well to fleeting sensations, thoughts, or images. Many thoughts and feelings cannot be expressed in language or illustrated in pictures. Words cannot describe faithfully the combinations of feelings and ideas that flood consciousness the moment one wakes up from a nightmare or sees a magnificent sunrise on a crystal-clear morning. (96)

For Vygotsky, the proper units of thinking are concepts—mental constructs that are expressible in words and that are often (although not necessarily) designated by a word in lexical memory and in speech and writing (see Collins & Loftus, 1975; Jaeger, 2005, 312). Words indeed play a crucial role in the formation of concepts; they come to symbolize concepts, which the child fully masters and learns to think with in adolescence. Yet one should be careful not to conflate language and thought. Different speakers and writers may use the same words, but use them differently for thinking (Vygotsky, 1934/1986, 96-145; cf. Kagan, 2006, 44-49).[35] For Vygotsky, intellectual maturity depends on one's ability to think in "scientific" (or classical) concepts, with well-defined intension and extension.

This perspective opens up a fruitful line of inquiry for history and philosophy of science. We should examine the language of science as a vehicle of conceptual meanings, which may not be expressed in words transparently (López Rúa, 2003, 25-31). In principle, the language of science differs from everyday language in that the use of scientific terms is normatively licensed by definitions. In everyday language the use of words is not: words assume determinate meanings in situations, and these meanings change from situation to situation (cf. Wittgenstein: "for a large

---

[35] For example, Vygotsky demonstrated that when preschoolers use the word "family," they do not mean the same thing as adults who use the same word: for a child, "family" designates a collection of named people ("Mommy, Daddy, Sally, … "); for an adult, "family" refers to an abstract and generalizable concept, with a determinate intension (a group of related individuals living together in a household). It is the adult use of the word "family" that Vygotsky terms a "scientific," or "genuine," concept. Adult, or "scientific," concepts allow for considerable cognitive economy; we do not have to learn extension by listing (Markman, 1989, 10).

class of cases … the meaning of the word is its use in the language"; *Philosophical Investigations*, sect. 143). This distinction between scientific and everyday language, however, is only clear-cut in theory. In practice we must inquire into how words convey conceptual meaning in different kinds of scientific writing at different periods and in different cultures.

For innovative scientists, new concepts may not come as a flash of lightning. They may evolve as a result of exploration, which falls short of "mathematical" conceptual precision. Some authors are less interested in developing a fully coherent system than others. Vygotsky's example of such an author is Freud, who was too deeply committed to observation and thinking from observation to develop a fully coherent high-level theory. To study thinkers such as Freud, Vygotsky believes, one has to put special effort into reading their texts philologically and analytically so as to reconstruct the system of ideas or concepts. Vygotsky himself is a thinker of this sort. He often makes use of what might be called "potential concepts"—ideas that seem to be fruitful, but that need to be additionally developed, defined, and tested in experimental practice to serve as full-fledged scientific concepts (cf. Davydov, qtd. Levitin, 1990, 61-62).

History of psychology strongly depends on philological and analytical reading of texts—especially texts written before the second half of the twentieth century, when psychological language began to take on a mature form.[36] Texts are important because they constitute the primary source of information concerning the scientific practices of psychologists (in the history of psychology there is much less artifactual evidence than in e.g. the history of physics). Since we gain knowledge of psychological practices from texts, we need reliable methods of text analysis to optimize our access to the thinking of psychologists. What is at stake here is the quality of scholarship in history and philosophy of science. The challenge is how to read texts non-impressionistically: how to represent the knowledge they contain; how to compare scientific

[36] Compare Vygotsky on scientific language in *The Crisis,* ch. 9 (1982/1997, 281-291).

approaches systematically, based on the analysis of concepts and arguments; and how to account for conceptual change and the development of knowledge within a domain.

What is needed, in the first place, is a working theory of concepts that allows us to analyze the conceptual structures expressed in scientific texts. The sources of such a theory should include the work of cognitive and developmental psychologists who have demonstrated that humans make use of different kinds of mental constructs and that language represents them in different ways (e.g. Vygotsky, 1934/1986; Hovland, 1952; Inhelder & Piaget, 1964; Bruner et al. 1966; Davydov, 1972; Rosch, 1973; Rosch & Mervis, 1975; Johnson-Laird, 1983; Markman, 1989; Medin & Coley, 1998; Barsalou, 1999; Carey, 1999; Baillargeon & Wang, 2002; Gelman, 2003; López Rúa, 2003; Mandler, 2004; Keil, 2005). Philosophers, such as Wittgenstein, contributed significantly to the understanding of concepts and language. There is a lot of work that remains to be done to clarify what concepts are, how they are processed mentally, how they are stored, how they are related to verbalization, how they are related to one another, how they develop in ontogenesis, how they develop in sociogenesis, and how they enter into propositions. In the recent decades significant advances have been made in these directions, as a part of the "cognitive turn" in psychology (Mandler, 2007; Shanker, 1997). It is a task for historians of science to review and understand psychological literature on concepts in order better to understand the conceptual structures that are conveyed by scientific texts.[37] On the basis of a theory of concepts and their expression in language, specific methods and tools of text analysis can be designed. Such methods and tools should be implemented in a research program that would study scientific texts as structures of knowledge.

[37] An excellent example of the application of psychological theories of concepts to the analysis of conceptual structures in a particular discipline—linguistics—can be found in López Rúa (2003). She also presents a useful survey of the existing theories of concepts.

Bibliography

Ainsworth, M., & Bowlby, J. (1965). *Child care and the growth of love*. London: Penguin Books.

Ainsworth, M. D. (1978) *Patterns of attachment: A psychological study of the strange situation*. Lawrence Erlbaum.

Armstrong, D.F., Stokoe, W.C., & Wilcox, S.E. (1995). *Gesture and the nature of language*. Cambridge: Cambridge University Press.

Baillargeon, R., & Wang, S.-H. (2002). Event categorization in infancy. *Trends in Cognitive Sciences, 6*, 85-93.

Bakeman, R. (2005). Observational methods. In B. Hopkins (ed.), *The Cambridge Encyclopedia of Child Development* (pp. 117-120). New York: Cambridge University Press.

Bakeman, R., & Gottman, J. M. (1997). *Observing interaction: An introduction to sequential analysis* (2nd ed.). New York: Cambridge University Press.

Barsalou, L.W. (1992). Frames, concepts, and conceptual fields. In A. Lehrer and E. Feder Kittay (eds.), *Frames, Fields, and Contrasts: New Essays in Semantic and Lexical Organization* (pp. 21-74). Hillsdale, NJ: Lawrence Erlbaum Associates.

Barsalou, L.W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577-660.

Bartlett, F.C. (1932). *Remembering.* Cambridge: Cambridge University Press.

Binswanger, L. (1922). *Einführung in die Probleme der allgemeinen Psychologie*. Berlin: Springer.

Boring, E.G. (1929). *A history of experimental psychology*. New York: Century.

Boring, E.G. (1942). *Sensation and perception in the history of psychology*. New York: Appleton-Century.

Boring, E.G. (1950). *A history of experimental psychology* (2nd ed.). New York: Appleton-Century-Croft.

Boring, E.G. (1963). *History, psychology, and science: Selected papers* (ed. R.I. Watson & D.T. Campbell). New York: Wiley.

Bowlby, J. (1958). The nature of the child's tie to his mother. *International Journal of Psychoanalysis, 39*, 1-23.

Bowlby, J. (1969). *Attachment and loss, Vol. 1: Attachment*. New York: Basic Books.

Broadbent, D.E. (1958). *Perception and communication*. London: Pergamon Press.

Bruner, J.S., Olver, R.R., & Greenfield, P.M. (1966). *Studies in cognitive growth*. New York: Wiley.

Bühler, K. (1918). *Die geistige Entwicklung des Kindes*. Jena: Verlag von Gustav Frischer. Russian translation 1924.

Büttner, J., Damerow, P., Renn, J., & Schemmel, M. (2003). The challenging images of artillery: Practical knowledge at the roots of the scientific revolution. In W. Lefèvre, J. Renn, & U. Schoepflin (eds.), *The power of images in early modern science*. Basel: Birkhäuser.

Carey, S. (1999). Sources of conceptual change. In E.K. Scholnick, K. Nelson, S.A. Gelman, & P.H. Miller (eds.), *Conceptual development: Piaget's legacy* (pp. 293-326). Mahwah, NJ: Erlbaum.

Chomsky, N. (1959). A review of B.F. Skinner's *Verbal Behavior*. *Language 35* (1), 26-58.

Clement, J. (1982). Students' preconceptions in introductory mechanics. *American Journal of Physics, 50* (1), 66-71.

Cole, M. (1995). Socio-cultural-historical psychology: some general remarks and a proposal for a new kind of cultural-genetic methodology. In J. V. Wertsch, P. del Río, & A. Alvarez (eds.), *Sociocultural Studies of Mind* (pp. 187-214). Cambridge: Cambridge University Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge: Harvard University Press.

Cole, M. (2002). Alexander Luria, cultural psychology, and the resolution of the crisis in psychology. *Journal of Russian and East European Psychology, 40* (1), 4-16.

Cole, M., & Scribner, S. (1974). *Culture and thought*. New York: Wiley.

Cole, M., & Scribner, S. (1981). *The psychology of literacy*. Cambridge, MA: Harvard University Press

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. *Psychological Review 82*(6), 407-428.

Craik, K.J.W. (1943). *The nature of explanation*. Cambridge: Cambridge University Press.

Damerow, P., Freudenthal, G., McLaughlin, P., & Renn, J. (2004). *Exploring the limits of preclassical mechanics* (2nd ed.). New York: Springer.

Davydov, V.V. (1972). *Vidy obobzhenija v obuchenii: logiko-psikhologicheskiie problemy postroeniia uchebnyh predmetov [Types of generalization in teaching: logical-psychological problems of creating a curriculum]*. Moscow: Pedagogika.

de Groot, A.D. (1946). *Het Denken van den Schaker*. Amsterdam: Noord-Hollandsche Uitgevers Maastschappij.

de Groot, A.D. (1964). *Thought and choice in chess*. The Hague: Mouton.

Denny, M.R. (1986). “Retention” of S-R in the midst of the cognitive invasion. In D.F. Kendrick, M.E. Rilling, and M.R. Denny (eds.), *Theories of Animal Memory*. Hillsdale, NJ: Lawrence Erlbaum.

Donaldson, M.L. (2005). Clinical and non-clinical interview methods. In B. Hopkins (ed.), *The Cambridge Encyclopedia of Child Development* (pp. 106-110). New York: Cambridge University Press.

Duncker, K. (1926). A qualitative study of productive thinking. *Pedagogical Seminary, 33*, 642-708.

Duncker, K. (1935). *Zur Psychologie des produktiven Denkens*. Berlin: Springer.

Duncker, K. (1945). On problem solving. *Psychological Monographs, 58*(5): ix, 113.

Engels, F. (1925/1978). *Dialektik der Natur.* Berlin: Dietz.

Fernyhough, C., & P. Lloyd (Eds.). (1998). *Lev Vygotsky: Critical assessments* (4 vols.) Routledge.

Flower, L. & J. R. Hayes. (1981). A cognitive process theory of writing. *College Composition and Communications, 32* , 365-87.

Flower, L. (1985). *Problem-solving strategies for writing* (2nd ed.). San Diego: Harcourt.

Flower, L. (1994). *The construction of negotiated meaning: A social cognitive theory of writing*. Carbondale: Southern Illinois University Press.

Fuchs, A. H., & Milar, K. S. (2003). Psychology as a science. In D. K. Freedheim & I. B. Weiner (eds.), *Handbook of Psychology: Vol.1, History of Psychology* (pp. 1-26). New York: John Wiley & Sons.

Gardner, H. (1985). *The mind’s new science: A history of the cognitive revolution*. New York: Basic Books.

Gelman, S.A. (2003). *The essential child: Origins of essentialism in everyday thought*. London: Oxford University Press.

George, C., Kaplan, N., & Main, M. (1985, 1996). *The adult attachment interview*. Unpublished manuscript. University of California at Berkeley.

Gierer, A. (1988). Spatial organization and genetic information in brain development. *Biological Cybernetics, 59*, 13-21.

Gigerenzer, G., & Sturm, T. (2007). Tools = theories = data? On some circular dynamics in cognitive science. In M. Ash & T. Sturm (eds.,) *Psychology's territories: Historical and contemporary perspectives from different disciplines* (pp. 305-342). Mahwah, NJ: Erlbaum.

Goldman, A.I. (1979). What is justified belief? In G. Pappas (ed.), *Justification and knowledge* (pp. 1-23). Dordrecht: Reidel.

Goswami, U. (2002). Models of cognitive development. In U. Goswami (ed.), *Blackwell Handbook of Childhood Cognitive Development* (pp. 509-514). Malden, MA: Blackwell.

Graham, Daniel. (1998). *Aristotle Physics Book VIII*. Oxford: Clarendon Press.

Granott, N., & Parziale, J. (eds.) (2002). *Microdevelopment: Transition process in development and learning*. Cambridge: Cambridge University Press.

Greenwood, J.D. (1999). Understanding the "cognitive revolution" in psychology. *Journal of the History of the Behavioral Sciences, 35* (1), 1-22.

Gregory, R. L. (1978). Illusions and Hallucinations. In E. C. Carterette & M. P. Friedman (eds)., *Handbook of Perception* (pp. 337-357). Vol. IX. Perceptual Processing. Eds.. New York: Academic Press.

Hebb, D.O. (1949). *The organization of behavior*. New York: Wiley.

Hebb, D. O. (1955). Drives and the C.N.S. (Conceptual Nervous System). *Psychological Review, 62*, 243-254.

Hevly, B. (1996). The heroic science of glacier motion. *Osiris, 11*, 66-86.

Hilgard, E.R., Leary, D.E., & McGuire, G.R. (1991). The history of psychology: A survey and critical assessment. *Annual Review of Psychology, 42*, 79-107.

Hovland, C.I. (1952). A "communication analysis" of concept learning. *Psychological Review, 59*, 461-472.

Humphrey, G. (1948). *Directed thinking*. New York: Dodd Mead.

Humphrey, G. (1951). *Thinking: An introduction to its experimental psychology*. New York: Wiley.

Inhelder, B., & Piaget, J. (1964). *The early growth of logic in the child.* New York: Norton.

Iser, W. (1993). *The fictive and the imaginary: Charting literary anthropology*. Baltimore: Johns Hopkins University Press.

Jaeger, J.J. (2005). *Kids' slips: What young children's slips of the tongue reveal about language development*. Mahwah, NJ: Lawrence Erlbaum.

Johnson-Laird, P. N. (1983). *Mental models*. Cambridge, MA: Harvard University Press.

Kagan, J. (2006). *An argument for mind*. New Haven: Yale University Press.

Katona, G. (1940). *Organizing and memorizing*. New York: Columbia University Press.

Keil, F.C. (2005). Knowledge, categorization, and the bliss of ignorance. In L. Gershkoff-Stowe & D.H. Rakison (Eds.), *Building object categories in developmental time* (pp. 309-334). Mahwah, NJ: Erlbaum.

Kemp, Simon. (1996). *Cognitive psychology in the Middle Ages*. Westport, Conneticut: Greenwood Press.

Koffka, K. (1924). Introspection and the method of psychology. *British Journal of Psychology, 15*, 149-161 (Russian translation 1926).

Koffka, K. (1925). *Die Grundlagen der psychischen Entwicklung*. Osterwieck am Harz: A.W. Zickfeldt.

Köhler, W. (1917). *Intelligenzprüfungen an Anthropoiden*. Berlin: Königliche Akademie der Wissenschaften.

Köhler, W. (1929). *Gestalt Psychology*. New York: Liveright.

Köhler, W. (1941). On the nature of associations. *Proceedings of the American Philosophical Society, 84*, 489-502.

Konstan, D. (2005). The emotions of the ancient Greeks: A cross-cultural perspective. *Psychologia: An International Journal of Psychology in the Orient, 48*(4), 225-240

Kornilov, K.N. (1922). *Uchenie o reaktsijakh cheloveka s psikhologicheskioj tochki zrenija ("reaktologija")* [*A psychological teaching on human reactions ("reactology")*]. Moscow: Gosudarstvennoje Izdatel'stvo.

Kozulin, A. (1991). *Vygotsky's psychology: A biography of ideas*. Cambridge: Harvard University Press.

Kurek, N. (2004). *Istoriia likvidatsii pedologii i psikhotekhniki [A history of the liquidation of paedology and psychotechnics]*. Saint Petersburg: Aleteiia.

Lamb, S., & Wozniak, R. (1990). Developmental co-construction: Metatheory in search of method. *Contemporary Psychology, 35*, 253-254.

Lashley, K.S. (1951). The problem of serial order in behavior. In L.A. Jeffress (ed.), *Cerebral mechanisms in behavior: The Hixon symposium* (pp. 112-146). New York: Wiley.

Leahey, T.H. (1992). The mythical revolutions of American psychology. *American Psychologist*, *47*(2), 308-318.

Leontiev, A.N. (1931). *Razvitije pam'ati. Eksperimental'noje issledovanije vysshykh psikhologicheskihk funktsij [The development of memory: An experimental investigation of higher psychological functions]*. Msoacow-Leningrad: Uchpedgiz.

Leontiev, A.N. (1932). The development of voluntary attention in the child. *Journal of Genetic Psychology, 40*, 52-81.

Leontiev, A.N. (1975). *Dejatel'nost', soznanije, lichnost' [Activity, consciousness, personality]*. Moscow: Izdatel'stvo Politicheskoj Literatury.

Leontiev, A.N. (2007). *Lektsii po obshej psikhologii [Lectures on general psychology]*. Moscow: Smysl.

Levina, R.E. (1968/2001). Idei L.S. Vygotskogo o planiruiushej rechi rebenka [L.S. Vygotsky on the planning speech of the child]. In L.F. Obukhova & G.V. Burmenskaia (eds.), *Jean Piaget: Theory, experiments, discussions* (pp. 79-89). Moscow: Gardariki.

Levitin, K.E. (1990). *Lichostju ne rozhdajuts'a [One is not born a personality]*. Moscow: Nauka.

Lew, A.R. (2005). Experimental methods. In B. Hopkins (ed.), *The Cambridge Encyclopedia of Child Development* (pp. 120-123). New York: Cambridge University Press.

López Rúa, P. (2003). *Birds, colors, and prepositions: The theory of categorization and its applications in linguistics*. München: Lincom Europa.

Lotringer, S. (1988). *Overexposed: Perverting perversions*. New York: Pantheon.

Mandler, George. (2007). *A history of modern experimental psychology: From James and Wundt to cognitive science*. Cambridge, MA: MIT Press.

Mandler, J.M. (2004). *Foundations of mind: The origins of conceptual thought*. New York: Oxford University Press.

Markman, E.M. (1989). *Categorization and naming in children: Problems of induction.* Cambridge, MA: MIT Press.

Medin, D.L., & Coley, J.D. (1998). Concepts and categorization. In J. Hochberg (ed.), *Perception and cognition at century's end: Handbook of perception and cognition* (pp. 403-439). San Diego: Academic Press.

Miller, G. A. (1956). The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review, 63*, 81-97.

Miller, G. A. (2003). The cognitive revolution: a historical perspective. *Trends in Cognitive Sciences, 7*(3), 141-144.

Milne, C. (1998). Philosophically correct science stories? Examining the implications of heroic science stories for school science. *Journal of Research in Science Teaching, 35* (2), 175-187.

Muir, D., & Slater, A. (eds). (2000). *Infant development: The essential readings*. Oxford: Blackwell.

Newell, A., & Simon, H. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Newell, A., Shaw, J.C., & Simon, H.A. (1958). Elements of a theory of human problem solving. *Psychological Review, 65*, 151-166.

Niesser, U. (1967). *Cognitive psychology*. Englewood Cliffs, NJ: Prentice Hall.

Nietzsche, F. (1911/1964). We philologists (J.M. Kennedy, trans). *The Complete Works of Friedrich Nietzsche* (vol. 8). New York: Russell & Russell.

Norman, J. M. (2005). On computable numbers (Introduction to Turing, 1936). In J.M. Norman (ed.), *From Gutenberg to the Internet: A sourcebook on the history of information technology* (pp. 301-302). Novato, CA: historyofscience.com.

Ortony, A. (ed.) (1979). *Metaphor and thought*. Cambridge: Cambridge University Press.

Parten, M. (1932). Social participation among preschool children. *Journal of Abnormal and Social Psychology, 27*, 242-269.

Pastalkova, E., Itskov, V., Amarasingham, A., & Buzsáki, G. (2008). Internally generated cell assembly sequences in the rat hippocampus. *Science, 321*, 1322-1327.

Perelman, C., & Olbrechts-Tyteca, L. (1958/1969). *The new rhetoric: A treatise on argumentation* (J. Wilkinson & P. Weaver, trans.). Notre Dame: University of Notre Dame Press.

Piaget, J. (1924/1959). *The language and thought of the child* (3rd. ed.; M. Gabain & R. Gabain, trans.). London: Routledge & Kegan Paul.

Piaget, J. (1926/1929). *On the child's conception of the world* (J. Tomilinson & A. Tomilinson, trans.). London: Routledge & Kegan Paul.

Peirce, C.S. (1931-1958). C. Hartshorne, P. Weiss, & A. Burks (eds.), *Collected papers of Charles Sanders Peirce* (8 vols.). Cambridge, MA: Harvard University Press.

Planck, M. (1919/1970). Das Wesen des Lichts. In M. Planck, *Vorträge und Erinnerungen* (pp. 112-124). Darmstadt: Wissenschaftliche Buchgesellschaft.

Pocock, J.G.A. (1973). Verbalizing a Political Act: Towards a Politics of Speech. *Political Theory, 1*, 27-43.

Poyatos, F. (1988). Literary anthropology: Toward a new interdisciplinary area. In F. Poyatos (ed.), *Literary Anthropology: New approaches to people, signs and literature* (pp. 3-49). Amsterdam: John Benjamins.

Renn, J., & Damerow, P. (2007). Mentale Modelle als kognitive Instrumente der Transformation von technischem Wissen. In H. Böhme, C. Rapp, & W. Rösler (eds.), *Überzetzung und Transformation* (pp. 311-331). Berlin: Walter de Gruyter.

Rosch, E. (1973). On the internal structure of perceptual and semantic categories. In T.E. Moore (ed.), *Cognitive development and the acquisition of language.* New York: Academic Press.

Rosch, E., & Mervis. C.B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology, 7*, 537-605.

Rummelhart, D.E., & McClelland, J.L. (1985). *Parallel distributed processing: Explorations on the microstructure of cognition*. Cambridge: MIT Press.

Sager, J.C. (1990). *A practical course in terminology processing*. John Benjamins.

Sakharov, L.S. (1928). Obrazovanije pon'atij u umstvenno-otstalykh detej (referat) [Concept formation in mentally retarded children]. *Voprosy defektologii, 2*, 24-33.

Sakharov, L.S. (1930). O metodakh issledovanija pon'atij u shkol'nika [On methods of studying concept formation in school children]. *Psikhologija, 3*, 3-33.

Selz, O. (1913). *Über die Gesetze des geordneten Denkverlaufs. Eine experimentelle Untersuchung*. Stuttgart: Spemann.

Selz, O. (1922). *Zur Psychologie des produktiven Denkens und des Irrtums*. Bohn: Cohen.

Selz, O. (1924). Die Gesetze der produktiven and reproductiven Geistestätigkeit. Bonn: Cohen.

Selz, O. (1927). Die Umgestaltung der Grundanschauungen vom intellektuellen Geschehen. *Kantstudien, 32*, 273-280.

Shanker, S. (1997). Reassessing the cognitive revolution. In D.M. Johnson & C.E. Erneling (eds.), *The future of the cognitive revolution* (pp. 45-54). New York: Oxford University Press.

Shepard, R.N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171*, 701-703.

Shieber, S. (ed.) (2004). *The Turing test: Verbal behavior as the hallmark of intelligence.* Cambridge: MIT Press.

Shif, Zh. I. (1935). *Razvitije nauchnykh pon'atij u shkol'nika. Issledovanije k voprosy umstvennogo razvitija shkol'nika pri obuchenii obshestvovedeniju [The development of scientific concepts in school children. An investigation of the mental development of the child in the process of civics education]*. Moscow-Leningrad: Gosudarstvennoje Uchebno-Pedagogicheskoje Izdatel'stvo.

Skinner, B. F. (1957). *Verbal behavior*. Acton, MA: Copley Publishing Group.

Swain, M. (1981). *Reasons and knowledge*. Ithaca, NY: Cornell University Press.

Taylor, D. J. (1977). Varro's mathematical models of inflection. *Transactions of the American Philological Association, 107*, 313-323.

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.

Tompkins, J.P. (1980). The reader in history. In J.P. Tompkins (ed.), *Reader-response criticism from formalism to post-structuralism* (pp. 201-232). Baltimore: Johns Hopkins University Press.

Tupper, D.E. (1999). Introduction: Alexander Luria's continuing influence on worldwide neuropsychology. *Neuropsychology Review, 9*, 1-7.

Turing, A.M. (1936). On computable numbers, with an application to the *Entscheidungsproblem*. *Proceedings of the London Mathematical Society, 2*(42), 230-265.

Turing, A.M. (1937). On computable numbers, with an application to the *Entscheidungsproblem*: A correction. *Proceedings of the London Mathematical Society, 2* (43), 544-546.

Turing, A. (1950). Computing machinery and intelligence. *Mind, 49*, 433-460.

van der Veer, R., & Valsiner, J. (1991). *Understanding Vygotsky: A quest for synthesis*. Basil Blackwell.

Vygotsky, L.S. (1925/1997). Preface to Lazursky. In *The collected works of L.S. Vygotsky. Vol.3: Problems of the theory and history of psychology* (pp. 51-61). Trans. R. van der Veer. New York: Plenum Press.

Vygotsky, L.S. (1926/1997). The methods of reflexological and psychological investigation. In *The collected works of L.S. Vygotsky. Vol.3: Problems of the theory and history of psychology* (pp. 35-49). Trans. R. van der Veer. New York: Plenum Press.

Vygotsky, L.S. (1928). Psikhologicheskaja nauka v SSSR [Psychological science in the USSR]. In *Obshestvennyje nauki v SSSR (1917-1928) [Social sciences in the USSR (1917-1927)*]. Moscow.

Vygotsky, L.S. (1928/2006). Problema kul'turnogo razvitija rebenka [The problem of cultural development of the child]. In *Psikhologija razvitija cheloveka* [*Psychology of human development*] (pp. 191-207). Moscow: Smysl.

Vygotsky, L. S. (1929). "The problem of the cultural development of the child II." *Journal of Genetic Psychology*, 36, 415-32. (translation of Vygotsky, L. S. (1928). Problema kul'turnogo razvitija rebenka. *Pedologija*, 1, 58-77.)

Vygotsky, L.S. (1930/1960). Instrumental'nyj metod v psikhologii [The instrumental method in psychology]. In L.S. Vygotsky *Razvitije vysshykh psikhicheskikh funktcij [The development of higher mental functions]* (pp. 224-134). Moscow: Izdatel'stvo APN RSFSR. (Also in J. Wertsch, ed., The Concept of Activity in Soviet Psychology.)

Vygotsky, L.S. (1930/2006). Orudije i znak v razvitii rebenka [Tool and sign in the development of the child]. In *Psikhologija razvitija cheloveka* [*Psychology of human development*] (pp. 1039-1129). Moscow: Smysl.

Vygotsky, L.S. (1931/1999). Pedology of the adolescent. In R.W. Rieber & J. Wollock (eds.), *The collected works of L.S. Vygotsky. Vol.5: Child psychology*. New York: Plenum Press.

Vygotsky, L.S. (1931/2006). Istorija razvitija vyshikh psikhicheskikh funktsij [The history of the development of the higher mental functions]. In *Psikhologija razvitija cheloveka* [*Psychology of human development*] (pp. 208-563). Moscow: Smysl.

Vygotsky, L.S. (1934/1986). *Thought and language*. Trans. A. Kozulin. Cambridge, MA: MIT Press.

Vygotsky, L.S. (1934/2005). Problema obuchenija i umstvennogo razvitija v shkol'nom vozraste [The problem of teaching and mental development in school children]. In *Pedagogicheskaja Psikhologija [Educational Psychology]* (ed. V.V. Davydov) (pp. 400-419). Moscow: AST, Astrel', L'uks.

Vygotsky, L.S. (1934/2006). Problema razvitija i raspada vysshykh psikhicheskikh funktsij [The problem of the development and destruction of the higher mental functions]. In *Psikhologija razvitija cheloveka* [*Psychology of human development*] (pp. 548-563). Moscow: Smysl.

Vygotsky, L.S. (1968/1971). *The psychology of art*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1982/1997). The historical meaning of the crisis in psychology. In R.W. Rieber & J. Wollock (eds.), *The collected works of L.S. Vygotsky. Vol.3: Problems of the theory and history of psychology* (pp. 233-343). New York: Plenum Press.

Vygotsky, L. S. (1989). [Concrete human psychology]: An unpublished manuscript by Vygotsky. *Soviet Psychology, 27*(2), 53-77.

Watson, R.I. (1963). The great psychologists: From Aristotle to Freud. Philadelphia: Lippincott. 4th ed. 1978.

Watson, R.I. (ed.) (1974). *Eminent contributors to psychology, Vol. 1: A bibliography of primary sources*. New York: Springer.

Watson, R.I. (1976). *Eminent contributors to psychology, Vol. 1: A bibliography of secondary sources*. New York: Springer.

Watson, R.I. (1978). *The history of psychology and the behavioral sciences: A bibliographic guide*. New York: Springer.

Wennerstrom, A. (2001). *The music of everyday speech: Prosody and discourse analysis*. Oxford: Oxford University Press.

Werner, H. (1956). Microgenesis and aphasia. *Journal of Abnormal Social Psychology, 52*, 347-353.

Wertheimer, M. (1945). *Productive thinking*. New York: Harper.

Wertheimer, M. (1970). *A brief history of psychology*. New York: Holt, Rinehart, & Winston. §rd ed. 1987.

Wertsch, J.V. (1985). *Culture, communication, and cognition: Vygotskian perspectives*. New York: Cambridge University Press.

Wertsch, J., & Tulviste, P. (1992). L.S. Vygotsky and contemporary developmental psychology. *Developmental Psychology, 28*(4), 548-557.

Wittgenstein, Ludwig (1953/2001). *Philosophical Investigations*. Blackwell.

Zavershneva, E.Ju. (2008). Zapisnye knizhki, zametki, nauchnye dnevniki L.S. Vygotskogo: rezul'taty issledovaniia semeinogo arkhiva [L.S. Vygotsky's notebooks, notes, and academic diaries: Some results of investigating his family archive.]. *Voprosy psikhologii, 1*, 132-145; *2*, 120-136.

Zimbardo, P. G. (2007). *The Lucifer Effect: Understanding how good people turn evil*. New York: Random House.

MAX-PLANCK-INSTITUT FÜR WISSENSCHAFTSGESCHICHTE

Max Planck Institute for the History of Science

Preprints since 2008 (a full list can be found at our website)

340 Uljana Feest, Giora Hon, Hans-Jörg Rheinberger, Jutta Schickore, Friedrich Steinle (eds.) **Generating Experimental Knowledge**

341 Sílvio R. Dahmen **Boltzmann and the art of flying**

342 Gerhard Herrgott **Wanderer-Fantasien. Franz Liszt und die Figuren des Begehrens**

343 Conference **A Cultural History of Heredity IV: Heredity in the Century of the Gene**

344 Karine Chemla **Canon and commentary in ancient China: An outlook based on mathematical sources**

345 Omar W. Nasim **Observations, Descriptions and Drawings of Nebulae: A Sketch.**

346 Julia Kursell (ed.) **Sounds of Science – Schall im Labor (1800–1930)**

347 Sophia Vackimes **The Genetically Engineered Body: A Cinematic Context**

348 Luigi Guerrini **The 'Accademia dei Lincei' and the New World.**

349 Jens Høyrup **Über den italienischen Hintergrund der Rechenmeister-Mathematik**

350 Christian Joas, Christoph Lehner, and Jürgen Renn (eds.) **HQ-1: Conference on the History of Quantum Physics (Vols. I & II)**

351 José M. Pacheco **Does more abstraction imply better understanding?** ("Apuntes de Mecánica Social", by Antonio Portuondo)

352 José Miguel Pacheco Castelao, F. Javier Pérez-Fernández, Carlos O. Suárez Alemán **Following the steps of Spanish Mathematical Analysis: From Cauchy to Weierstrass between 1880 and 1914**

353 José Miguel Pacheco Castelao, F. Javier Pérez-Fernández, Carlos O. Suárez Alemán **Infinitesimals in Spain: Antonio Portuondo's *Ensayo sobre el Infinito***

354 Albert Presas i Puig **Reflections on a peripheral Paperclip Project: A technological innovation system in Spain based on the transfer of German technology**

355 Albert Presas i Puig **The Contribution of the History of Science and Social Studies to the Understanding of Scientific Dynamics: the Case of the Spanish Nuclear Energy Program**

356 Viola Balz, Alexander v. Schwerin, Heiko Stoff, Bettina Wahrig (eds.) **Precarious Matters / Prekäre Stoffe.** The History of Dangerous and Endangered Substances in the 19th and 20th Centuries

357 Florentina Badalanova Geller ***Qur'ān* in vernacular.** Folk Islam in the Balkans

358 Renate Wahsner & Horst-Heino v. Borzeszkowski **Die Naturwissenschaft und der philosophische Begriff des Geistes**

359 Jens Høyrup **Baroque Mind-set and New Science.** A Dialectic of Seventeenth-Century High Culture

360 Dieter Fick & Horst Kant **Walther Bothe's contributions to the particle-wawe dualism of light**

361 Albert Presas i Puig (ed.) **Who is Making Science? Scientists as Makers of Technical-Scientific Structures and Administrators of Science Policy**

362 Christof Windgätter **Zu den Akten – Verlags- und Wissenschaftsstrategien der Wiener Psychoanalyse (1919–1938)**

363 Jean Paul Gaudillière and Volker Hess (eds.) **Ways of Regulating: Therapeutic Agents between Plants, Shops and Consulting Rooms**

364 Angelo Baracca, Leopoldo Nuti, Jürgen Renn, Reiner Braun, Matteo Gerlini, Marilena Gala, and Albert Presas i Puig (eds.) **Nuclear Proliferation: History and Present Problems**

365 Viola van Beek **„Man lasse doch diese Dinge selber einmal sprechen" – Experimentierkästen, Experimentalanleitungen und Erzählungen um 1900**

366 Julia Kursell (Hrsg.) **Physiologie des Klaviers.** Vorträge und Konzerte zur Wissenschaftsgeschichte der Musik

367 Hubert Laitko **Strategen, Organisatoren, Kritiker, Dissidenten – Verhaltensmuster prominenter Naturwissenschaftler der DDR in den 50er und 60er Jahren des 20. Jahrhunderts**

368 Renate Wahsner & Horst-Heino v. Borzeszkowski **Naturwissenschaft und Weltbild**

369 Dieter Hoffmann, Hole Rößler, Gerald Reuther **„Lachkabinett" und „großes Fest" der Physiker. Walter Grotrians „physikalischer Einakter" zu Max Plancks 80. Geburtstag.**

370 Shaul Katzir **From academic physics to invention and industry: the course of Hermann Aron's (1845–1913) career**

371 Larrie D. Ferreiro **The Aristotelian Heritage in Early Naval Architecture, from the Venetian Arsenal to the French Navy, 1500–1700**

372 Christof Windgätter **Ansichtssachen. Zur Typographie- und Farbpolitik des Internationalen Psychoanalytischen Verlages (1919–1938)**

373 Martin Thiering **Linguistic Categorization of Topological Spatial Relations.** (TOPOI – Towards a Historical Epistemology of Space)

374 Uljana Feest, Hans-Jörg Rheinberger, Günter Abel (eds.) **Epistemic Objects**