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Reconstructing Cognitive Transfer

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Abstract

In this paper, two main types of cognitive transfer theories are identified: The Thorndikean approach, concerning the isolation of elementar communalities between learning situations, and the Gestaltist approach, viewing transfer in terms of the alignment of schematic representations. Reconstruction of cognitive transfer aims at the unification of these rivaling theories, whose differences may be caused by implicit presuppositions rather than reflected in empirical evidence. The presented conceptualization of transfer reinterprets the traditional theoretical trenches in terms of different transfer dimensions. Two key theoretical notions are introduced: *apperception* and *content-based* explaining. Rather than on shared cognitive constituents, transfer is described as dependent on the apperceptional act to functionally reconcile communalities and differences when constructing a novel, sense-making representation of the transfer situation.

Reconstructing Cognitive Transfer

The need for foundational reconstruction of transfer theories

The phenomenon of transfer, familiar to all psychologists, is a relation between two learning situations. In the first, primary learning situation, people learn something that affects how they process (e.g. perceive, represent, understand, perform at, learn etc.) something else in a following, secondary learning situation. Naturally, some transfer takes place in every moment we do or learn something. What is previously learned during engagement with some materials always penetrates the process of “dealing” with new, but somehow mentally related, material. Or, stated the other way around, we never encounter a life situation without making use of something we have experienced and learned earlier. However, from the point of scientific research into the nature of the transfer phenomenon, we must speak about transfer in two senses. In a broad sense, transfer refers to any effect of previously learned materials on current information processing. In narrow sense, it is a change in processing taking place in a specific setting, e.g. an experiment.

Ideally, transfer empirics attempt to investigate the effect of primary learning on secondary learning by comparing the effects or the processes taking place to control conditions, where, apart from these experimental primary learning situation, transfer relevant learning resources should be equal to all participants including the control group, i.e. for the latter no primary learning has taken place or it has been very different by nature (see e.g. Ellis, 1965). The main problems are here that primary and secondary learning situations have to be chosen, defined and constructed by the experimenter, and it his or her challenge to define and explain accurately which and how certain aspects of the primary situation account for the improved or hampered information processing in the latter.

Different psychological functions can be accentuated when discussing the phenomenon of transfer. One can focus on work pertaining to cognitive transfer with its variety of subtypes, which, to a large extent, includes transfer of motor skills (Adams, 1987; Bassok, 1990; Bovair, Kieras, & Polson, 1990; Brown, 1989; Catrambone, 1996; de Crook, van Marriënboer, & Paas, 1998; Elio & Anderson, 1981; Ferrari, 1999; Gentner & Gentner, 1983; Gick & Holyoak, 1980, 1983; Holland, Holyoak, Nisbett, & Thagard, 1986; Logan, 1988; Reed, 1993; Robertson, 2001; Ross, 1987, 1989; Schmidt, 1988; Schmidt & Young, 1987; Shea & Morgan, 1979; Singley & Anderson, 1985, 1989; Thorndyke & Hayes-Roth, 1979). But, one can also approach transfer from a perspective that has received far less attention: emotional and social transfer (Bandura, 1969, 1971, 1986; Barnes & Thagard, 1996; Oatley & Johnson-Laird, 1987, 1996; Scherer, 1995; Thagard, 2000; Thagard & Shelly, 1997, 2001; Vygotsky, 1962). Although, in a truly integrated theory of transfer, the distinction between cognition and emotion in transfer will hardly be as clear-cut, we concentrate in this apper on cognitive transfer. This means, transfer in which the elements explaining transfer are cognitive by nature. We choose cognitive transfer partly because it has been over the last century the most active transfer research domain. And, partly, because its theoretical and empirical body offers a good opportunity to start a reconstructive endeavour.

The simplicity of the basic intuitive notion of transfer makes it very surprising that, despite a rich theoretical and empirical research base, persistent disagreements can be found in cognitive literature concerning the phenomenon. These pertain to different theoretical views about the conditions under which transfer occurs, about what is transferred when something is transferred, or about how transfer is mediated. This has repeatedly encouraged the creation of transfer typologies and taxonomies (see Barnett & Ceci, 2002; Butterfield, 1988; Detterman, 1993; Gagné, 1977; Langley, 1985; Reeves & Weisberg, 1994; Salomon & Perkins, 1989; Singley & Anderson, 1989), signifying that differences in views are not only historical but also synchronic. Consequently, also the ways in which transfer is operationalized have differed substantially between various researchers. Finally, one can find in literature obvious transfer phenomena, which seldom are seen as such. Priming is perhaps the most obvious example of a tacit transfer, and can be brought in close relation to research of transfer-appropriate processing (TAP) (Francis, 1998; Francis, Jameson, Augustini, & Chavez, 2000; Franks, Bilbrey, Lien, & McNamara, 2000) and La Fave's (1958) habit lag construct. This means that we are still not very certain of what we speak when talking about transfer. Reconstructive stance is essential in searching for an outcome and clarification in this kind of situation.

Reconstructive work is a type of foundational analysis and aims at resolving differences (Saariluoma, 1997). It refers to research into the theoretical and intuitive foundations of argumentative chains in the hope of finding tacit conceptual, theoretical and empirical reasons for disputes and differences in opinions between researchers. Indeed, if there is a difference in scientific conceptions, and it is impossible to find trivial methodological errors made by one side, it is necessary to search for an explanation regarding the differences in the foundations of approaches (Saariluoma, 1997). There is no alternative explanation for the differences in conceptions. In practice, this means that the intuitive presuppositions causing differences in positions are investigated and explicated. On the grounds of this information, it is possible to look for a more general theoretical vision to the field and attempt to reconstruct the basic argumentative chains.

The purpose of reconstructive work on transfer is to supply research with a solid conceptual basis and to move closer to the formulization of a unified theoretical approach to transfer. The key to this lies in a meta-scientific approach to transfer analysis and reconstruction, as shall be explicated in the final chapter of this paper. This has, so far, not been done thoroughly enough, which is not to say that one cannot find historical and paradigmatical reviews of theoretical developments and differences regarding the transfer phenomenon (e.g. Adams, 1987; Cormier & Hagman, 1987; Cox, 1997; Greeno, Collins, & Resnick, 1996; Haskell, 2001; Mayer & Wittrock, 1996). Calls to move transfer up in the research agenda of cognitive psychology have become stronger, at last with the influential book by Singley & Anderson (1989) on the transfer of cognitive skills. One hundred years of transfer research since the original work by Thorndike and Woodworth (1901a, b, c) provide a rich treasure of empirical data and have produced a variety of theoretical attempts to explain the phenomena. Thus, the time seems ripe to start to integrate and reconstruct the theoretical foundation for cognitive transfer.

To carry out such a program, we begin with a presentation of the major theoretical frameworks and respective empirical operationalizations. For this we divide the theoretical field into two rivaling types of approaches to transfer. These types coincide with holistic versus elementaristic views on cognition and especially learning (see below for a more detailed demarcation of the theoretical families). By penetrating into the structure of the respecting theoretical and empirical concepts, we see whether it is possible to detect intuitions, i.e. tacit non-explicated presuppositions or conceptual postulates, i.e. ultimate theoretical concepts, which presuppose different things about the phenomenon of transfer (for meta-theoretical notions and an explication of the whole approach, see Saariluoma, 1997). Our goal will be to present a theoretical notion, that, while old in itself, is new to transfer, and shall serve to integrate different explanations of transfer into a unified conceptual framework.

The two families of theoretical approaches to transfer

The notions of transfer developed partly driven by the dominant psychological paradigms such as Associationism and Connectionism, Behaviorism, Gestaltism, and Cognitivism, but also by the important application fields like educational psychology, human-computer interaction, verbal learning and inter-language transfer. Nevertheless, the development has not taken place in the form of emerging "theoretical isles" with no connections between each other. We rather see families, in which a number of theoreticians have had very similar basic assumptions which evolved to the present root paradigms. Typically, the families have always had deep differences in some, though not in all, fundamental questions.

What unites all of the families - probably the prevailing issues in transfer - are the notion of *learning* and the idea of *similarity*. It is a widely shared intuition that transfer is due to some similarity between a primary and secondary learning experience (Gentner, 1989; Gentner, Holyoak, & Kokinov, 2001; Gentner, Rattermann, & Forbus, 1993; Holyoak & Koh, 1987; Katona, 1949; Ross, 1984, 1987, 1989). A thorough investigation of the notion of similarity itself (signifying the relationship between two objects that are the same in some respect, yet different others), and a comprehensive analysis of the different ways it is understood has seldom been conducted (see Vosniadou & Ortony, 1989, for such an interdisciplinary account). It has often been based on common sense: everybody knows what similarity is. It is central to our analysis to realize the unchanged fact, that this very basic concept is understood differently between researchers.

Here, we shall discuss two basic theoretical approaches to transfer. They are common element-based and schematic theories of transfer. Distinct from Barnett and Ceci's (2002) recently proposed diversified taxonomy for far transfer only, our focus is much more on transfer mechanisms and we attempt to touch on the bottom of theoretical disputes attached to the far-near distinction itself. By the concept of common element–based transfer we refer to the theories that investigate transfer as mediated by common elements. They decompose primary and secondary learning into elements, seeing the similarity between the learning situations as a function of shared components (this is particularly obvious in works associated with Singley and Anderson's approach). By schematic transfer theories we refer to ideas in which transfer is thought to be caused by schematic similarity (see Reed, 1993; Reeves & Weisberg, 1994). Both traditions are very deeply rooted in our western culture and their distinction finds parallels in many other transfer-related contrasts: e.g. specificity vs. generality, knowledge- vs. problem-solving transfer, near vs. far transfer, low-road vs. high-road transfer. During the last century, the two positions were especially embodied in the differences between behaviorists' conceptualization of learning as a rote mechanism and Gestaltists' emphasis of insightful learning. However, their roots can be traced further back to the disagreements between Locke (1690) and Leibniz (1704), and possibly reflect disagreements on the conception of memory and representations between Plato and Aristoteles (see Wedin, 1988).

Transfer by common elements

The common element-based view on transfer emerged in pre-behaviourist American psychology. As a reaction to the understanding of transfer as depending on the exercise of general functions of the mind such as attention, memory and reasoning (Binet, 1899; Thorndike, 1924a, b), Thorndike and Woodworth (1901a, b, c) conducted a series of classic experiments in search of *specificity* in mental functions as well as the spreading, or carrying over, of acquired proficiency to other (closely) related functions. Their operational objective was the measurement of lower sensomotoric processes such as the area-judgment of a series of differently shaped and sized paper pieces under conditions where reference areas and feed-back was provided for improving the amount of correct answers (primary learning situation), and under no-reference and no-feedback conditions (secondary learning situation). The authors conclude from their data that transfer of proficiency doesn't go much beyond direct practice effects – an interpretation of empirical evidence that has shown great persistence throughout the last century (e.g. Detterman, 1993). Hence, transfer is seen as limited by and to the identical elements shared in the learning situations. Clearly, this is an explanation in concepts of classical associationism (Locke, 1690; Hume, 1960; Mill, 1843). The central question that Thorndike and Woodworth were able to address by their experimental design was the one about how similar the "magnitudes of paper piece sizes" (proportional scale) have to be in order to be perceived as "equal". It is however important to realize, that Thorndike and Woodworth – other than often portrayed – actually made inferences into the subjective reality of mind, i.e. stimulus perception of their subjects. They did, although, not follow this investigative trail any further, and thus left that development of the common-elements approach open to cognitive scientists much later in the 20th century.

The behaviorists developed the same core idea, introduced by Thorndike, to the their own extreme, proposing a surgically exact examination of objective source and transfer "material" in terms of a complete determination of overlapping stimulus and response elements. They relied initially on Pavlovian stimulus and response differentiation and later turned to Skinner (1953) and his theoretical framework. Important concepts such as stimulus generalization or the power of association were developed (e.g. Guthrie, 1935, 1942; Hull, 1943; Osgood, 1949).

The common element notion allowed for a variety of interpretations (Ellis, 1965) and was applied effectively in education (e.g. learning hierarchies; see Gagné, 1968; Thorndike, 1903, 1906), the training of motor skills (e.g. specific repetition of training elements and part-whole transfer of training; see Adams, 1987, p. 511ff.; Adams & Hufford, 1962; Briggs & Brodgen, 1954; Briggs & Naylor, 1962; Henry & Rogers, 1960; Shea & Kohl, 1990), and the development of behavior therapy within clinical psychology (e.g. Wolpe, 1969). It also influenced linguistics and was applied in the analysis of language (see Powell, no date), before Noam Chomsky's (1959) famous critique undermined behaviourist argumentation and made their very conceptual system look problematic.

Modern versions of common-element theories

The cognitive shift in psychology opened new possibilities to the analysis of transfer situations and explication of the common element idea (Anderson 1983, 1985, 1993; Anzai & Simon, 1979; Atwood & Polson, 1976; Eysenck & Keane, 2000; Hayes & Simon, 1974, 1977; Kuhn, 1970; Lachman, Lachman, & Butterfield, 1979, Neisser 1967, Newell & Simon, 1963, 1972; Simon & Hayes, 1976). Here, we refer to two major implementations of the common elements approach within Cognitive Science. They are GOMS and ACT– computational models of mind (Anderson, 1982, 1983, 1993, 1996; Anderson & Lebiere, 1998; Card, Moran, & Newell, 1980, 1983; Kieras & Polson, 1982, 1985). Both architectures are built upon the premises of the production system approach (Newell & Simon, 1972) and have been used to explicate common-element theories of transfer.

A production system model with GOMS is derived through the analysis of a user' s knowledge of how to carry out routine skills in terms of *g*oals, *o*perations, *m*ethods, and *s*election rules. A key problem related to this architecture has been interaction with and transfer between IT-devices or systems, which has been seen as a function of shared production rules (Bovair et al., 1990; Kieras, 1988; Kieras & Bovair, 1986; Kieras & Polson, 1985; Polson, Muncher, & Engelbeck, 1986). Naturally, this is a new type of common element theory of transfer (called *cognitive complexity theory (CCT)*), which is mostly applied to HCI and cognitive engineering (Bovair et al., 1990; John & Kieras, 1994, 1996a, 1996b; Lewis & Polson, 1990; Polson, Lewis, Rieman, & Wharton, 1992). In one of the initial studies in this area, Kieras and Bovair (1986) examined whether representations of procedural knowledge subjects had acquired from instruction text, i.e. in terms of production rules, allow for the prediction of transfer from one task to a related one. They found that speed and accuracy in performing the transfer task were clearly a function of the overlap of procedures, and that the amount of this was well predicted by their simulation program.

An alternative to GOMS for longer than twenty years has been Anderson's ACT-architecture (*Adaptive Control of Thought;* see Anderson, 1976, 1982; 1983, 1992, 1993; Anderson & Lebiere, 1998), which combines symbolic frameworks of production systems with connectionist models and consists of two long-term memory stores, i.e. declarative and procedural memory. As with transfer explained by the CCT, the main focus of ACT has been on production rules as common elements. Production rules are seen as a generalized or compiled (proceduralized) knowledge form, relying on knowledge from instances and examples, i.e. the declarative prerequisites. The compilation process itself is seen as a summarization of the repeated analogical use of exemplary knowledge in an early learning phase.

Since productions, once compiled, are viewed as highly use-specific (e.g. the proposal of asymmetric access; Singley & Anderson, 1989, p. 224), and their access and application as largely automatic, questions arose regarding the flexible use of knowledge in transfer across knowledge domains and specific contexts of use (Anderson & Fincham, 1994; Müller, 1999; Pennington & Nicholich, 1991; Pennington, Nicholich, & Rahm, 1995). Similar questions also fueled the debate between Anderson's rule-based theory and Logan's instance theory, i.e. in how far exemplary knowledge is preserved, accessed and employed during transfer, after proceduralization of knowledge has taken place (Anderson & Fincham, 1994; Logan, 1988, 1990). Rabinowitz and Goldberg (1993) produce ample evidence for the partial artificiality of this debate, since type of knowledge acquisition and its transfer across tasks largely depends on the chosen tasks, the involved stimuli, and conditions under which training and transfer takes place.

Conceptualised in terms of an overlap of knowledge units, the ACT-architecture can model a variety of transfer situations, namely *declarative-to-declarative*, *procedural-to-procedural*, *declarative-to-procedural*, and *procedural-to-declarative*. Declarative-to-declarative transfer has been studied in a very straightforward fashion: Facts, once known, need not be learned anymore, no matter in what knowledge domain or context a familiar concept appears. Thibadeau, Just, and Carpenter (1982), for example, observed that an already known word or concept in a different text requires 686ms less gazing time (see also Harvey & Anderson, 1996). Declarative-to-procedural transfer may be seen in knowledge compilation when new and previously encapsulated knowledge is used to construct new procedures (Singley & Anderson, 1989). One typical example could be problem-solving transfer (see also Bovair & Kieras, 1991; Brooks & Dansereau, 1987; Dixon & Gabrys, 1991; Harvey & Anderson, 1996; Royer, 1986; Singley & Anderson, 1989). Because procedural-to-declarative (-to-procedural) transfer depends largely on preserved and re-extractable declarative knowledge, ACT-R allows for this type of transfer only at a stage where a compiled production rule has not yet been fully strengthened (Anderson & Fincham, 1994).

The operationalization approach widely favored in testing for procedural transfer is to have participants learn artificial production rules in terms of mathematical calculation rules or functions defined within a program language (e.g. LISP). This experimental paradigm serves mainly two purposes: the controlled application of a procedural rule, employing relative simple and “meaningless” declarative material (numbers and operators), and the availability of an inverse to the rule (Anderson & Fincham, 1994; Anderson, Fincham, & Douglass, 1997; McKendree & Anderson, 1987; Kessler, 1988; Müller, 1999; Pennington & Nicholich, 1991; Pennington et al., 1995).

In Anderson and Fincham’s (1994) experiments, rules consisted of adding and/or subtracting values to two digits. For instance, subjects were tested with problems such as 34*b*, while *b* stands for +1, +2, and had to respond by producing 46. In reverse, the rule *b* became -1, -2. However, it is difficult to conceive +1, +2 as procedural inverse to –1, -2, without reference to an extracted declarative knowledge *about* the rule. Accordingly, Anderson and

Fincham (1994) found little evidence for instance-to-instance and procedural-to-declarative transfer, nor did they find counterevidence to their asymmetry proposal. More transfer benefits to reverse conditions have been demonstrated with the evaluation-generation paradigm using LISP functions, which allows for the acquirement of richer (more meaningful) declarative knowledge about procedures (Pennington & Nicholich, 1991; Pennington et al., 1995).

Generally, modern versions of the common-element approach to transfer differ in several ways from the original. They focus on a variety of units of transfer and provide a more detailed description of the units which are believed to match between transfer source and transfer target. They also have the power to model these elements as combinable and chunkable mental units. They often assume architectural models with genuine processing capacities. Finally, they introduced a much more task- and domain-oriented perspective on the transfer phenomenon.

Nevertheless, it can be argued that the cognitivists' interpretation of Thorndike's identical elements theory and the development into a procedural-to-procedural transfer theory (see also Moran, 1983; Polson & Kieras, 1985; Singley & Anderson, 1985, 1989) does not signify a great deal more than the development step from the S-R to the S-O-R paradigm. "O," in the production system terminology, is then defined as a production rule (condition-action pair), combined with the necessary declarative and procedural knowledge or memory (Anderson, 1995; Hull 1952, Newell & Simon, 1972, Tolman 1932). Certainly, this change, in combination with the support available in terms of modelling techniques, allowed cognitive scientists to simulate and test their inferences into the "black-box" of transfer processing. It did however not emancipate the common element approach from its central characteristics of atomicity and specificity, and its automatic and mechanistic manner

(Koffka, 1925; Larkin, 1989), nor did it liberate the predictive limitations of the model, which are set to near transfer issues, i.e. tasks of close proximity within a knowledge domain.

Schematic transfer

The atomistic and mechanistic presuppositions underlying the common-elements approach produced critic especially with the Gestaltists and eventually gave raise to an alternative tradition in transfer research. The roots for these ideas can be followed back to Judd's (1908, 1939) critic on Thorndike's transfer theory. While Judd's experiment was not really a test of self-induced, spontaneous transfer, he could nevertheless demonstrate that theoretical knowledge about the general principle involved in a task, can - without prior practice - lead subjects to outperform those of a control group who were given the chance to specifically practice their proficiency on a similar task, but received no general instruction. Inside the often-used framework of *specific* versus *general* transfer, Mayer and Wittrock (1996) characterize the Judd-Thorndike debate as the position supporting "*specific transfer of general skill,*" as opposed to "*specific transfer of specific behavior.*"

The rising Gestalt movement continued Judd's (1908) line of work and resulted in further accentuation of "insightful" transfer, using terms like knowledge *structures* and *schemata*, solution *principles,* and *functionality* (Katona, 1949; Wertheimer, 1959). In a careful attempt to reconstruct the theoretical basis of learning and transfer, Koffka (1925) reinvestigated the experimental data of Thorndike (1911, 1913) and Köhler (1917). He maintained that learning as an inadvertent combination of elements and their mechanistic transfer to situations cannot be upheld, because even animals can select and distinguish relevant aspects form irrelevant ones on the grounds of their value to the attainment of a situational goal. Similarly, Selz (1913, 1922) argued against the classical association theory, and prepared the field for schematic transfer researchers with his interpretation of thinking as a senseful and *directed* process, constantly seeking to complete knowledge structures to meaningful wholes. Solving a problem, according to Selz, means to *comprehend* it, which he interpreted as resolving novelty by arranging the *new* within the *old*, i.e. by enhancing a previously acquired schema of related problems (the proximity of this idea to transfer is evident).

Convincing evidence against the common-elements idea came thus initially from the classical experiments conducted by Köhler (1917), where chimpanzees transferred solutions by employing tools that were not even part of the presented primary or secondary problem situations during transfer. In this, Gestaltists went even further than Judd (1908, 1939) in their holistic attitude (Humphrey, 1924). Neither identicality in stimuli elements, nor commonality on a generalized level in terms of theoretical knowledge about a problem provide by themselves sufficient explanatory power to point out what mediates transfer. And for that matter, the data of these early Gestaltist experiments also showed that transfer can hardly be a phenomena limited to the repetitional execution of already acquired procedures, as proposed much later by supporters of the production system approach. A new concept had to be introduced, namely one of a *"functional relationship"* (Köhler, 1917) between the structure and parts of a source problem and those of a transfer problem, even if a transposition of the original structure is needed. This is indeed rather different from the "proportionality-relationship" (Allport, 1937) proposed by common-elements theories, where the amount of transfer is bound to be between 0 and 100%, thus proportional to the degree of shared identical elements present both during primary and secondary learning situation (Katona, 1949).

Still in the spirit of Selz's anticipatory schema theory, and in accordance with the functionality approach introduced by his Berlin Gestalt colleagues, Duncker (1935) identified in his analysis of problem-solving two main principles that can easily be linked to the phenomenon of transfer: *transformation* and *resonance.* Transformation refers to the need to develop or restructure a problem so that the current one is basically “replaceable” by an old (already solved) one (Duncker, 1935; Selz, 1913, 1922). The functional significance of the old problem’s solution (principle) is then transferred and has to be reconciled with the objectives, restraints and conditions of the current one. At this point the detection principle of resonance kicks in, which anticipates and recognizes those elements, part of the current problem, that can be fitted (assimilated) as the missing parts into the working schema (compare Selz, 1922). This leads to a new concretisation of the functional significance of the transferred solution.

Mental effort becomes crucial when a critical element to instantiate a solution is not featured in a subsequent problem set. In this case the subjects are forced to search for a functional substitute for the left open “gap” in the solution schema. This often calls for what Wertheimer (1945/59) termed “Umzentrierung,” and the downside to it – namely the inability to find something from which the anticipated characteristics can be abstracted – has been investigated by Duncker (1935) under the header of *functional fixedness*. Subjects had to solve a problem where a critical object had to be used, first, in accordance with its ordinary purpose and, subsequently, for an unusual (transfer) function. Compared with other subjects who were not primed with the “ordinary use” situation, the experimental group performed significantly worse. The distinction between ordinary and unusual function of an object became crucial, with the claim that functional fixedness can only be observed in the direction of ordinary-to-unusual use, not the opposite (DiVesta & Walls, 1967; Duvall, 1965; Flavell, Cooper & Loiselle, 1958; Ray, 1965; Van de Geer, 1957).

More in the spirit of Judd’s initial experiments – and clearly more cited than the above mentioned functional transfer type - has been problem solving transfer with respect to learnable and teachable solution principles. A range of experiments was done to investigate the acquirement and transfer of general rules and strategies (see Bourne, Ekstrand, &

Dominowski, 1971, p. 104ff.). Usually subjects were either previously confronted with the extracted rule (explicit training of the principle) or had to solve problems that worked by the same principle (implicit training of the principle). Different types of positive and negative effects on performance in transfer tasks could be shown, as a function of the rule presentation and the training on related and unrelated problems: e.g. practice effects, priming effects, set effects.

Overall, the Gestaltists' holistic influence did not necessarily signify a total rejection of the assumptions made in specific transfer theories, e.g. the common-elements idea itself. Like Judd, Gestaltists' partially relied on "common elements" in terms of problem solving strategies and principles. However, it definitely liberated transfer theory from its restriction to stimuli dependency and atomistic transfer. And, in accordance with the Gestaltist psychological paradigm, active transfer and cognitive effortful recognition of a problem's structure became key (*"transfer by insight"* and *"high-road"*-transfer; Salomon & Perkins, 1989), rather than automatization on a shallow perceptional and behavioral level (*"low-road"*-transfer). It also led to a categorical separation of transfer issues into *knowledge transfer* (based on the idea of learning as rote memorizing), and *problem-solving transfer* (learning by understanding) (Katona, 1949; Mayer & Wittrock, 1996), reviving the question about domain-limitations of transfer (Larkin, 1989).

Modern schema-based transfer theorists

Modern holistic analysis of transfer situations is an heir of the thought psychology introduced by the Berlin and the Würzburg schools. The focus remained on problem solving and on the type and quality of the individual's representation of source and target problem (Gott, Hall, Pokorny, Dibble, & Glaser, 1993; Novick, 1990; Novick & Hmelo, 1994). In this family of research, the main emphasises have been on analogical reasoning and mental models. Analogical transfer has been seen as being either based on concrete exemplars (Ross, 1984, 1987, 1989), mediated by abstracted rules and schema (Gick & Holyoak, 1980, 1983; Holland et al., 1986; Holyoak, 1984a, 1984b, 1985; Holyoak & Thagard, 1997), or due to structural correspondence (Clement & Gentner, 1991; Gentner & Gentner, 1983; Gentner & Toupin, 1986). In all three cases, the main explanatory concepts are the *organization of knowledge representation* and the process of *mapping* correspondences between objects, features, attributes, relationships and structures, and problem-solving aims (Reed, 1993; Reeves & Weisberg, 1994), not shared atomic elements. Differences between the theories arise from the type of analogy constraints they emphasise: *semantics* (concrete feature similarity), *syntactics* (structure similarity), and *pragmatics* (contextual and goal-related similarity).

The typical experimental design for measuring analogical transfer is having subjects solve one problem and measure the subsequent time taken, the number of appropriate and inappropriate solution steps, paths and products in a transfer problem. The latter problem lends either its structural systematicity from the original problem to different degrees (Gentner & Toupin, 1986), contains the same solution logic and same rules (Simon & Hayes, 1976) with slightly altered move restrictions (Reed, Ernst, & Banerji, 1974), or incorporates the same abstracted principle and aims (Gick & Holyoak, 1980). Gick and Holyoak's fortress problem was designed as an *isomorphic* variant (i.e. common underlying structure and solution principles embedded into different contexts or cover stories) to Duncker's (1935) radiation problem. Other popular sources for problem versions have been the "Tower of Hanoi" (Simon & Hayes, 1976) or the "Missionaries and Cannibals" problem (Greeno, 1974; Reed et al., 1974; Thomas, 1974). While good results with isomorphic problems were obtained when presented in sequence with slight increase in difficulty (Forgus & Schwartz, 1957; Hildegard, Irvine, & Whipple, 1953; Reed, 1993; compare also *sequence effect*, Hull, 1920; Sweller, 1980), it remained the general conclusion that a subject's problem solving and transfer abilities are highly affected by semantics and surface similarity. This resulted in the repeated questioning of the extent to which subjects actually represent the solutions of the problems on which they trained in an extracted, schematic form. Instead of the development of a renewed conceptual framework, this boosted old support for the view that knowledge is largely bound to specific stimuli and contexts (compare also proponents of the *situated learning* thesis: Cobb & Bowers, 1999; Greeno, Moore, & Smith, 1993; Lave & Wenger, 1991) and that solutions remain encapsulated in the memory of the specific training exemplars (Medin & Ross, 1989). Thus the debate remained within the theoretical framework of *specificity* versus *generality*. Ross (1987) presented different experiments that play with the momentum of superficial similarity in analogical problem solving. In one experiment subjects received study and test problems in which the storyline and the objects involved were either largely unchanged ("same"-condition), the relationships of the same objects were arranged in reverse (however not affecting the functionality of the relationship; "reverse"-condition), or the story-line and/or objects were semantically unrelated. The ability of subjects to use relevant solution methods was greatly confined by the boundaries of superficial similarity, even when the common principle was explicated to them. However, the salience of surface details, when learning tasks are presented in word problem format (e.g. Reed, 1993; Ross, 1987), in combination with the usually extraordinary contents of such problems, might in many cases have also resulted in an overemphasis of superficiality and domain-specificity. Retrieval and transfer of an analog was further affected by the degree of contrastive distinctiveness of the learning problems (Ross, 1987), a "Prägnanz"-factor for reminding also identified by Gestaltists (Duncker, 1935).

Somewhat different from schema theories, mental models provided an alternative basis for the study of transfer, referring to adaptive expertise, i.e. knowledge and skills that are generalizable and adaptively applicable across contexts and domains of complex problem-solving tasks (Brown & Burton, 1986; Gentner & Stevens, 1983; Gott, 1989; Kieras & Bovair, 1984). The chances that lie within such an approach have already been recognized by proponents of the procedural transfer approach, and indeed, seem to find high applicability especially in the field of HCI. John and Kieras (1996) note that helping a user to acquire an appropriate representation, in terms of the working principles of the device, may substantially improve learnability and transfer. Gott, et al. (1993), presented such a knowledge assessment in a naturalistic transfer-environment of complex electronic trouble-shooting. The authors combine in their model “how-to-do-it”-procedural knowledge with “how-it-works”-system knowledge and general search strategies. The latter knowledge type is also a clear reference to the meta-cognitive and self-regulative themes in learning which have played a major role in transfer discussions especially within educational psychology (Brown, 1978; Brown & Campione, 1981; Campione & Brown, 1987; Mayer & Wittrock, 1996; Shraw & Brooks, 1998; Zimmerman, 1995). The more solid the abstract knowledge representations of their subjects were, and the more able and willing they were to employ general search strategies when specific procedures did not lead to successful transfer, the better they performed under change-(i.e. transfer)conditions (Gott et al., 1993). This implies a critic on the mechanistic procedural transfer theory, which is supported also by Karat, Boyes, Weisgerber and Schafer (1986), who found that experienced users of a word editor can be completely blocked from all transfer due to a single, non-matching procedure. However, this another conclusion of Gott et al., no matter how exhaustive and complex the cognitive skill architectures and mental models are, they tell us little about what particular similarities and dissimilarities are sufficiently salient to affect transfer of learning in the case of each individual.

The instability of transfer

Instability of transfer has haunted empirical research and affected the theoretical robustness of the concept. It is widely concluded that transfer between diverse contexts is generally hard to demonstrate in experimental settings (Bassok & Holyoak, 1989; Borowski & Cavanaugh, 1979; Campione, Brown & Ferrara, 1982; Cooper & Sweller, 1987; Cormier & Hagman, 1987; Detterman, 1993; Gelzheiser, Shepherd, & Wozniak, 1986; Gick & Holyoak, 1980; 1983; Haskell, 2001; Hayes & Simon, 1977; Lave, 1988; Lawson, 1986; Novick, 1988, 1990; Reed, 1987; Reed et al., 1974; Schliemann & Acoily, 1989; Simon & Reed, 1976; Stokes & Baer, 1977; Ward & Gow, 1982). Most commonly, transfer failure is attributed to difficulties in flexible access of knowledge: knowledge is described as inert, situatively bound, or domain and use specific - to the effect that it is occasionally questioned whether transfer occurs at all (Anderson, Reder & Simon, 1996, 1997; Bereiter & Scardamalia 1985; Brown, 1989; Brown & Campione, 1981; Campione & Brown, 1978; Cobb & Bowers, 1999; Greeno et al., 1993; Greeno et al., 1996; Greeno, 1997; Singley & Anderson, 1989). All of this obviously conflicts with the general notion about the omnipresence of transfer as part of everyday learning. There are three main sources for explanations of this seeming instability "paradox": There *are* natural boundaries to when, where, and how transfer occurs, the experiment may implement such barriers or other forms of artefactual transfer obstacles, or transfer might have occurred but was not detected because of inappropriate theoretical concepts and empirical measures.

Most experiments are designed based on a simplicistic similarity idea, namely to present subjects with learning and transfer situations that evoke some common experiences (i.e. shared production elements or schematic matches). Logically, problems arise when the researcher's similarity expressions differ from the subject's mental representation, or when the subjects did not acquire the experimentally relevant knowledge in the primary learning situation. Further, if meaningful transfer is to occur, the presented problems have to be understood on a meaningful level. Reed et al. (1985), confronted their subjects with triplets of algebra word problems, either in a "related-equivalent-similar"-sequence (experimental group), or, the two test problems were preceded by an irrelevant problem (control group). Like other experiments using transfer hints or direct instructions (DiVesta & Walls, 1967; Gick & Holyoak, 1980; Goldbeck, Bernstein, Hillix & Marx, 1957; Reed et al., 1974; Scandura, 1966), they found transfer improvement on an equivalent problem, but not on a "similar" problem (i.e. one which needs a slight modification of the transferred solution formula). The fact that subjects were not able to successfully modify the solution formula, even when this was available on a reference sheet, suggests that no sufficiently profound conceptual understanding was acquired.

Brown (1989) argues that the failure to demonstrate transfer is often an artefact caused by a fundamentally wrong empirical paradigm. Often, so her argument, it is the explicit intention of the experimenter to "trick" the subjects in such a way as to maximize the chance that similarities between primary and secondary learning are not recognized. Partially based on an analysis of two classic Gestaltist principles - Luchins' (1942) "*Einstellung*" and Duncker's (1935) "*functional fixedness*" – Brown suggests that transfer is more likely when the experimenter actively engages in creating a positive learning set (e.g. the establishment of some kind of routine to search for analogues), encourages the subjects to use knowledge in flexible forms (by avoiding dominating and rigid priming conditions) in order to facilitate reconceptualizations of critical transfer concepts (Lockhart, Lamon & Gick, 1988), and supports the reflection on one's own learning experiences (Brown, 1989).

Transfer interferring Einstellung effects – by nature, a sort of schema automatization – have been documented rather frequently. Using Duncker's (1935) resonance concept it is suggested that the solving of a series of problems, of which each prompts the activation of the same anticipatory schema and the search for a filler-element to serve the same recurring functional purpose, leads to development of a *set*, i.e. a habit or disposition to transform similar problems in a certain way to find resonance (see also Luchins, 1942). This will show its effect preferably when subjects are given many learning trials with a common solution approach, followed by *one* transfer trial.

In this context, it must be suggested that the excessive concern of laboratory transfer research with behavioral "outcome" measures comes at the expense of investigating the mental process itself. It is for example often ignored that a human learner may need a series of attempts to figure out an optimal source and mapping strategy for transfer. Experiments functioning under the "one-trial, no-feedback" maxim risk trading off transfer findings against the argument of contamination of data due to learning on the transfer problem itself. This is important to emphasize because hindering and enhancing effects of transfer are just two sides of the same cognitive process of transfer, i.e. positive and negative effects are always mixed in transfer. Through a more detailed analysis of the types of solution paths employed, Reed et al. (1985), for instance, were not only able to reveal more significant differences in transfer between the experimental groups, it also became clear that much of the inability to solve similar problems was not due to the failure to transfer, but rather due to "over-matching" of the problems, resulting in initial negative transfer.

Instead of investigating *whether* transfer occurs, research may profit by returning back to the initial question about *how* subjects transfer. Empirically this may require a much more qualitative approach to investigate the mental processes involved in transfer (Gott et al., 1993). Attempts to prompt subjects to reflect on their problem solving can be found in a few other experiments (e.g. Anderson & Fincham, 1994; Reed, Dempster, & Ettinger, 1985; Wattenmaker et al., 1995), but they are usually not very elaborate and lack the sophistication of the rest of the experiment. There are certainly parallels in these last suggestions to the paradigmatical and operationalizational debate about empirical paradigms between Bühler (1908b) and Wundt (1907) at the onset of experimental psychology. In the next chapter we will return to one theme of their dispute, concerning psychological content versus form as grounds of research.

On the other hand, there also appear some consistent findings in terms of “natural” restraints of transfer to be taken into account. The most classic one is the tendency of human beings to rely on superficial cues in retrieving past knowledge. This perceptual and stimuli-oriented conclusion seems at first self-evident, since no one can attend to underlying deep structures of an externally induced situation before perceiving it on a stimulus level. Further, perceptually-bound similarity recognition is not only a phylogenetically and ontogenetically old principle, much more, it is outside of the artificial world of the laboratory usually also an adaptive one (Brown, 1989; Gentner et al., 1993; Medin & Ortony, 1989). While theories in the Thorndikean tradition by nature emphasized stimuli confinedness of transfer, within schema theories superficial dissimilarities have usually been more like a scapegoat for explaining transfer failure between schematically analogical problems. This is what gave rise and support for Ross’ (1987) superficial constraint theory of schema transfer. The problem with this stimuli-confined notion is that it represents neither a truly psychological concept nor can it easily explain how a physician, for example, would be able to transfer his skills from customary hospital surroundings to the saving of lives in the superficially very dissimilar context of a military battlefield. That means, mapping problems become appearent even with analogs close to the “literal” (Gick & Holyoak, 1983) end of the similarity dimension. What we really need is a re-formulation of the same ideas within a content-constraint theory of transfer. Or in terms that translate easier to the similarity idea in transfer, “what we want to find out is precisely the psychological equality despite dissimilarity in a physical or other respect,” (Bühler, 1908b, p. 107-108), and vice-versa.

Problems and resolutions

After reviewing theories and experiments of the major schools of cognitive transfer it is obvious that there exist two rather different positions with respect to transfer. Both approaches, common-elements and schema-based, are built upon far backward reaching cultural intuitions, which present the basic question about the nature of transfer differently. Both, cognitive architectures as well as the schema framework did contribute to advancements in the pursuit of a mental account of transfer, but they do not allow us to get close enough to the mindful processes involved in the transfer phenomenon itself (see also Weisberg & Alba, 1981). And looking into the future of transfer research, they also do not seem powerful enough to absorb other aspects of multifaceted transfer, besides those confined to cognition in a restricted sense, e.g. socio-emotional dimensions of transfer. For all these reasons they cannot provide us with a unified view to what transfer is.

As to the differences between the two traditions, we are not able settle them on such trivial grounds as the parties having conducted poor experiments. The data put forth by the respective empirical bodies are solid and trustworthy. Thus, when we cannot refute nor resolve differences on an empirical level, the issues are very probably foundational (Saariluoma 1997). It is therefore essential to consider their conceptual and intuitive foundations, because the explanation for the failures in empirical refutation may be found in differences in intuitive understanding of the theoretical notions. In the case of reconstructing cognitive transfer we shall suggest a third point of view that could conceptually and theoretically unify the two approaches.

The issue, in which common elements theories differ from schema theories, is the nature of the theoretical concepts required in constructing and interpreting experiments. Whilst schema theorists emphasize the role of abstract schematic analogies, common element theories rely on elements (e.g. knowledge facts and production rules). It is conceptually manifest that schema theories should explain how schemas are bound to the elements (e.g. Kokinow & Petrow, 2001) and common element theories should provide us with information about the accurate organization of the common elements into wholes. Indeed, schema theorists would argue, for their part, that the stated demand has largely been met, and that the mapping of schemas involves elementar attributes as well as relations between them. Thus, from the perspective of a multilevel nature of analogy representations (Kintsch & Van Dijk, 1978), the theoretical concepts appear to be complementary. As such, schema experiments may or may not share similarities in elements. However, although the key criteria within schema theories concerning the relational properties of problem structure has been enhanced by a series of complementary constraints, such as semantic constraints stemming from the superficial feature matches between the analogies (e.g. Ross, 1987), or pragmatic factors (Holyoak, 1987), a reconciliation with common-elements proposals has not really been aspired. This is also true because schema theorists have mostly been very attracted by the idea of *content-free* schema; a problematic proposal with which we try to deal in our reconstructive argumentation.

Common-element research, for its part, has traditionally demonstrated limited effort to interpret its own findings from a unified theoretical perspective. While Anderson and Fincham (1994), for instance, actually employ schematic learning tasks in their experiments, they do not really pay attention to this factor during operationalization. Their empirical perspective does not anticipate the integration of this momentum into their theoretical framework. This is simply because all their procedural variations of the task functioned within an unmodified schema and unaltered stimuli-domain, and their experimental design is clearly based on the induction of consistent mental contents. We have already earlier argued for a similar operationalization effect in Thorndike and Woodworth’s experiments, which were, in fact, compatible with the later theory of procedural transfer, but could not formulate it because there was no intent to do so. In the same way, it has also to be realized that without schematic learning and transfer, the execution of procedural operations within Anderson and Fincham's "ab_*rule*_cd"-terms would hardly be possible. There are also numerous schematic similarities between text editors (Singley & Anderson, 1989). Thus, the complementary character of basic concepts can actually be seen on an empirical level as well.

But both traditional theoretical approaches also have some decisive shortcomings. While their emphasis is on elementar communality and schema alignment respectively, they have little to offer to the integration of discriminate parts in transfer representations. This is especially true with the common-element theory's difficulties to explain negative transfer (Singley & Anderson, 1989). That means, non-shared elements, structural discrepancies, and semantic differences between primary and secondary learning situations have usually been excluded from transfer formulations, or blamed for transfer failure. That is, the probability and magnitude of transfer seems always promoted by shared constituents - schemata or elements - and is decreased by non-shared constituents. However, in successful transfer itself, we must be able to fuse same and different mental constituents to a new whole in our mental representation of the secondary learning situation. Therefore we have to concentrate not only on how sameness causes transfer, but how transfer can involve differences. To some extent this has been attempted with Holyoak's (1985) introduction of the term "structure preserving differences".

Furthermore, whereas common-element experiments have preferably been designed using meaningless learning material and automated tasks, which by themselves may favor outcomes that are conform with the production system thesis, analyses of schema transfer have concentrated on high effort processes such as memory retrieval and mapping. And while the latter type of high effort cognitive transfer may truly take place in many real life situations, it may also be that what we would like to consider as mental transfer process is accomplished before anything from our memory has been retrieved as such, and thus ready to be mapped. Moreover, the explanation of this search-retrieval prerequisite of transfer has been the stage for circular argumentation. This is because the retrieval of a high-potential candidate for transfer mapping can only be achieved when mapping, to some extent, has already occurred. Thus, the explanatory power of "similarity," which is usually used to estimate the transfer value of a retrieved schema or episode, vanishes inevitably within the circularity of the similarity argument itself: Similarity has to bear being both a cause and a consequence of transfer.

Let us draw together the key points of the problems illustrated so far by setting out the stage for reconstructive resolutions. Transfer, as we see it, is ultimately based on the unification of parts and wholes, and the accomplishment to integrate same and different mental contents from primary and secondary learning situations. And, in coming to terms with the tacit concept of "memory source-perceived target"-comparison, built into the transfer-metaphor itself, we would like to argue for transfer as occurring continuously "on the spot." This means we should be able to get a clear idea about the mental processes involved in constructing mental representations during secondary transfer situations. The two key theoretical notions we use here are *apperception* and *content-based* explaining.

Apperception refers to the construction of mental representations (Kant, 1787; Leibniz, 1704; Miller, 1993; Saariluoma, 1990, 1992, 1995, 1997, 2001; Stout, 1896; Wundt; 1880). It is this notion that helps us to overcome both Thorndikean stimulus-confined explanations of transfer as well as later perception-bound approaches. One may easily think that mental representations are perceptional products, making the notion of apperception seemingly redundant. However, and this is where content-based explaining comes in, thinking mental contents, this cannot be true. We have numerous non-perceivable elements in our mental representations. We cannot perceive tomorrow Napoleonic wars, infinity, eternity, God, possible and impossible, constitutions, foreign trade, WWW, etc. We can perceive things only when they have a physical presence on our receptors. The "art of observing" (Mill, 1843), while related to the apperception-theme proposed here, is limited simply because it discusses only stimulus-bound situations. This is obvious not only with behaviorists but especially also with experiments in the Gestaltist tradition because of their experimental presupposition that stimuli are visible.

In addition, the apperception thesis suggests that we cannot understand what we perceive unless our conceptual knowledge is unified to it. We can listen to a discussion in a foreign language and hear everything without understanding a word. For this kind of reason, it is important to make a difference between "seeing something" and "seeing something as something" (Wittgenstein, 1953). This means also that for conceptual reasons we have to make a difference, as so many classic philosophers did, between perception and apperception.

Nevertheless, apperception is not an easy concept to understand, because it presupposes that we change our way of conception of mentality. We have to accept representational contents as being an equally important explanatory category as neural substrate, limited capacity or format (Saariluoma, 1997, 1999). Schema-based experiments perfectly illustrate how similarity in contents between situations may help or hinder us in "seeing" what are the important aspects of new situations (Gick & Holyoak, 1980, 1983; Reed, 1993; Reed et al. 1985; Ross, 1987). William James (1890), following John Locke (1690), used in this context the term *sagacity* to signify the importance of selecting and constructing an appropriate mental representation of an object (see also Lockhart et al., 1988). Thus, while there are many psychological questions, which can well be answered on the grounds of mental format and capacity, there are also many questions, which can best be answered on the grounds of the mental content. Apperception psychology works to answer the latter type of questions (Saariluoma, 1990, 1995, 2001, Saariluoma & Maarttola, in press).

On the basis of these notions we can now develop some additional understanding about the nature of transfer. Firstly, investigating apperception in transfer situations allows for the acknowledgment of the on-the-spot character of transfer. It takes place at the onset of encountering a transfer situation and applies to any instance in the continuous stream of making sense of world encounters. Such encounters occur with the outer world (objective reality) as well as with the inner world of fantasy and memory, including very different sorts of mental contents such as emotional (ratiomorph) responses, additional to those pertinent to the classical notion of mental representation. Transfer effects are, in essence, key to the construction of meaning in any experience. Transfer (i.e. the influence of past experience on current one), at the same time, shapes the spectacles of apperception and lends it its mental contents.

Investigating apperception in transfer also supports the presupposed construction of mental representations entailing both shared and new mental constituents. If the construction of such a representation fails, no transfer takes place. Therefore, the key issue becomes understanding under which conditions and by what processes it is possible to apperceive a transfer situation by account of a unified and integrated representation. From a content-based explanatory point of view this means that one must answer this problem: What type of mental content makes it possible to unify same and different detached elements and their relational structure (schema) in transfer representations.

In working with chess players and architects, it has been possible to demonstrate one content-based explanatory factor, the functional and sense-making relation between the elements of mental representations (Saariluoma, 1990, 1992, 1995, 2001, Saariluoma & Maarttola, in press). Functional relations between elements mean that each element in a representation has some purpose or reason to be in that representation. Almost a century ago, Karl Bühler (1907, 1908a) introduced similar ideas in his analysis of thinking, noting that thoughts – the units of thinking – are placed into sense-making relations with each other. And understanding, Bühler further elaborates, results when current thought relations are logically arranged within past experiences. The reader will notice the closeness of this proposal to the transfer theory presented here. After Bühler, the ideas have been taken and further developed into schema theories of comprehending (Selz, 1922; explicated in the chapter on schematic transfer) and reasoning (Minsky, 1975). But, above all, the Gestalt psychologists intuitively understood that the notion of function might have an important role to play in human thinking (Köhler, 1917; Koffka, 1925; Duncker, 1935). While the functional fixedness theorem was built around the way we "see" a certain object, it is obvious that the object's function actually results from the apperceived type of relationship it has with other objects (i.e. content elements in mental representation). Thus, functional fixedness can be applied to explain the effects of how a well known schema may not prompt transfer even with elements at hand that would fit the implementation of the schema in secondary learning. The reason for this is that the representation of how the critical element should be functionally related to other elements does not allow for their apperceptive integration in a transfer representation. Only when we succeed in reconciling or loosening the functional restraints of transferred heterogeneous content relations, can a unified representation be constructed.

Functional relations are generally answers of the type "in order to…," "therefore," "to reach this aim…," and so on. These kinds of relations are typical of practically all human constructions and this is why it is not strange that the constituents of mental representations are organized around webs of such systems of reasons. From a contents point of view, functional relations seem to be a very important precondition of forming representations. And indeed, the systematicity principle within Gentner's (1983) structure-mapping theory already allows for the inclusion of causal relations as higher order relations in representations. Likewise, Gick and Holyoak (1983) discuss the importance of mapping those schema elements which preserve the causal structure within analogs and Brown (1989) emphasizes the value of the functional versatility and congruency between (apperceived) systematicites encountered in a primary and a secondary (transfer) learning situation.

And ultimatively, this is why the analysis of apperceptive transfer should be able to explain and explicate the functional relations between mental constituents when constructing a representation of a secondary learning situation. This means, what are the sense-making relations between shared content elements – e.g. schemas and common elements – and new elements integrated into representations? It is not decisive to have shared contents but to be able to find and explicate the functional relations between them and new information.

Concluding comments

The main message of this paper is clearly of meta-theoretical nature. The fact that we look back on a century of, if not competing, at least not unified traditions of transfer, tells us that empirical work alone cannot resolve differences in argumentation. There is not much to be said negatively about the main experiments conducted, neither under the common-elements nor the schema paradigm. Rather, the disagreements seem to be products of underlying theoretical and intuitive presuppositions. As Hanson (1958) and others have shown the situation, where empirically sound but theoretically non-unanimous approaches challenge the same concept, is not rare in psychology. We may think, for example, of the long disputes surrounding mental images and computational models (Kosslyn 1980, 1994; Newell and Simon 1972, Pylyshyn 1973, 1986, Searle 1980, 1990, Simon 1996). The keys to coping with such a “cul-de-sac” lie in experimental presuppositions and theory-laden character of facts (Hanson, 1958; Saariluoma, 1997). Data and facts depend on theories and tacit intuitions. Experiments are constructed to investigate hypotheses, which are defined by the interpretations of the key theoretical notions, in this case, the notion of transfer. For this reason, one cannot understand science on an empirical level only, but it is necessary to pay attention to theories, concepts and even tacit intuitions underlying the construction and interpretation of experiments (Saariluoma, 1997).

Hence, the way we understand transfer may vary decisively, depending on our notion of transfer. Schema theoretical transfer experiments are constructed to demonstrate the importance of shared schemas. Common element theories, on the other hand, are designed to demonstrate the significance of common elements. Finally, it has been suggested that both conceptions can be subsumed under the classic idea of apperception (Kant, 1781; Leibniz, 1704; Wundt, 1880). For such a theoretical suggestion it must now be attempted to find support in the continuation of a thorough foundational analysis of available empirical data as well as by data produced in own experiments. This work is currently under way. Nevertheless, it seemed necessary to us to present the traditional and new theoretical frameworks at first alone in an initial paper, in order to set out the stage of the reconstructive program.

The dependence of our understanding of such an important notion as transfer on our half-intuitive interpretations made it also seem important to go back to Kant and his followers, who have emphasized the limits of our theoretical concepts as being the limits of our understanding. The question is not only about observations, but also about concepts that provide frames for our observations. The solution to these problems lies within the foundational investigation of concepts and their presuppositions. Foundational type of analytical work is rare in psychology, but there are few arguments to present why modern psychology should not be built on conceptually more consistent grounds, especially since sychology is very much a science in which the phenomenon of theory-ladenness is obvious

(Saariluoma 1997). Unresolved disputes and unanalyzed theoretical debates, such as the one regarding cognitive transfer, undoubtedly justify a reconstructive stance.

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