JYVÄSKYLÄ STUDIES IN COMPUTING
59

Sacha Helfenstein

Transfer

Review, Reconstruction, and Resolution

JYVÄSKYLÄN YLIOPISTO

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UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2005

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Esitetään Jyväskylän yliopiston informaatioteknologian tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston Agora-rakennuksessa (Ag Aud. 3)
joulukuun 28. päivänä 2005 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Information Technology of the University of Jyväskylä,
in the Building, Agora, (Ag Aud. 3), on December 28, 2005 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ

JYVÄSKYLÄ 2005

Transfer

Review, Reconstruction, and Resolution

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Publishing Unit, University Library of Jyväskylä

URN:ISBN:951392386X
ISBN 951-39-2386-X (PDF)

ISBN 951-39-2356-8 (nid.)
ISSN 1456-5390

Jyväskylä University Printing House, Jyväskylä 2005

ABSTRACT

Helfenstein, Sacha
Transfer. Review, Reconstruction, and Resolution.
Jyväskylä: University of Jyväskylä, 2005, 114 p. (+ articles)
(Jyväskylä Studies in Computing
ISSN 1456-5390; 59)
ISBN 951-39-2386-X
Finnish summary
Diss.

Starting out with a broad review of transfer research, i.e., the study of the dependency of human conduct on prior experience, the thesis elucidates the hampering current day situation of empirical, psychological, and conceptual segmentation. Broadly spread themes of interest are uncovered and linked to the three basic questions about where or when transfer takes place, what is carried over, and how this exchange is mediated. In the main, reconstructive part of the thesis, two distinct families of theoretical traditions are discerned and identified as common element-based and schema-based conceptualization of transfer. Conceptual cohesion within these traditions is shown to be overshadowed by some very basic controversies between them. The thesis continues by arguing for a content-based psychological approach resulting in the proposal of the content- and apperception-based theory of transfer. Mental contents and apperception are identified as the essential medium and process mechanism establishing transfer as a cognitively instantiated relation or concordance between mental representations. A key theoretical and methodological message is inherent to the propagated move away from looking at mental format and capacity issues in operationalization towards the identification of critical, in particular non-perceivable kinds of mental contents in representations. Empirical support is presented in the context of the four original publications. It is demonstrated that content-based research can reveal variability in experimentally induced transfer that is not predictable based on traditional theoretical notions. The findings are explained on the bases of the inter-dependency between the dynamics in mental contents (such as the apperceived use of objects or thought models) and their bindings to integrative representational wholes during apperception. Overall, the thesis contributes to the resolution of theoretical diversity and conflicts by impacting research on a meta-theoretical level. The reconstructed theory of transfer is also shown to have the capacity to reveal novel aspects to the phenomenon. A future pursuit and development of the content-based approach is strongly suggested.

Keywords: transfer (learning), apperception, content (psychology), mental representation, review (literature), learning theories, paradigm (theory of knowledge)

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AKNOWLEDGEMENTS

"Whether you think that you can or you can't you are usually right". This quote from Henry Ford has been ringing in my head in the final stages of writing this thesis like the voices of the Sirenes. But this work is naturally not merely the product of what I thought I can do; it echoes the faith and support of many people who believe in me.

First of all I want to express my deep gratitude for the trust and inspiration I received from Pertti Saariluoma. It was his experience, viewpoints, and passion for science that sparked so many ideas, and essentially drove this research ahead. Both personally and professionally, I look forward to fruitful collaboration and many lively debates in future with him.

A special merit also goes out to this thesis' oponent Hannakaisa Isomäki, and to the reviewers Eeva Kallio and Marjaliisa Rauste-von Wright. All invested highly valued Christmas time to evaluate my work. Their expert and insightful comments deserve my admiration and have been highly appreciated.

Naturally, there are many people at the University of Jyväskylä, mainly from Agora, that have opened important doors, guided my steps, and accompanied me in different phases of my journey over the last three and a half years. Of these I would like to compliment foremost Heikki Lyytinen, Samuli Pekkola, and Pekka Neittaanmäki. Also the helpful remarks and eagle eyes of Seppo Puuronen and Steve Legrand deserve extra mentioning.

My time at Agora Center has been precious to the initiation of this work and my acclimatization in Finland and in the University research circle. This would have never been the same without a whole bunch of people, of whom I would like to mention Päivi Parikka, Esa Kannisto, Päivi Fadjukoff, and Marja Kankaanranta. After my transfer I have also received a most warm welcome at the Department of Computer Science and Information Systems. I am still in the fascinating process of getting to know many of you. Within the User-fiendly Information Technology Program it was my pleasure to work with Hanna Parkkola and Markus Bengts. As a postgraduate student I have profited and truly enjoyed the seminars organized by Tuuli Hyvärinen within the INFWEST.IT program. I am afraid that the date of defending my thesis just came along too quick in this respect.

The thanks expressed to the before mentioned circle of people bring me to the value of friendship. Over the course of my university years I have made many precious friends that have a great stake in the realization of this thesis and in my joy at work. Thank you Caro, Timo, Jonne, Tiina, and Sami!

Without any doubt, the most valuable and truthful of all kinds of friendship has been given to me by my family. I would like to dedicate this work to my mother, my father, and my sister for their persistent support and the pride they take in me. The same is true for Trudi and Alfred. Writing was never the same art anymore after working at Fetscherin PR. I am also blessed

with a great new Finnish family. You have warmed my heart and soul on many cold Finnish days.

And thus, remain the three women that are most dear to me: Riitta, Sara, and Jasmin. You have made many sacrifices for making this thesis possible. Now that it is done, it is the occasion to buy a horse. And it is the time to get married. What do you say?

Jyväskylä
December, 2005

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III Helfenstein, S. & Saariluoma, P. Analyzing apperception in transfer. First submitted to Quarterly Journal of Experimental Psychology. To be resubmitted.

IV Helfenstein, S. (2005). Product meaning, affective use evaluation, and transfer. Human Technology, 1(1), 76-100.

"Without it we couldn't engage in our everyday thinking and reasoning nor even acquire the most basic of motor skills; transfer is responsible for the simplest of ideas and for the highest achievements of humankind"

(Haskell, 2001).

1 INTRODUCTION

1.1 The thesis in a nutshell

In the current thesis I will follow along the territorial trails of different accentuations, conceptions, and research traditions of transfer, uncover prevailing trenches between them, and explicate them as being caused by an underlying discord inherent to the conceptual foundations of the theoretical postulations. Two partly conflicting views on transfer are identified: a *common element*-based approach, rationalizing transfer as an effect of atomistic correspondences, and a *schema-based* approach, explaining transfer on the basis of conformity among relational structures. Picking up on the momentum of revived interest in transfer from a cognitive perspective, a real need for theoretical consolidation and empirical advancement is recognized. As a resolution the thesis proposes and explicates the application of content-based psychological concepts to transfer research.

The approach taken in this thesis is a reconstructive one. It is, at its inception, based on a review (see Chapter 2) and then on a foundational analysis (Saariluoma, 1997) of transfer research from the last 100 years (see Chapter 3). The purpose of this endeavour is to examine and evaluate the concepts and theories that have been used to investigate transfer, and to clarify how the models and the presuppositions inbuilt into them have influenced respective attempts to empirically substantiate the assumptions of the various research groups. The analysis and discussion of the research shall allow for a critical assessment of agreements and dissonances between different approaches and conceptualizations of transfer. As a result of this, the reader is also provided with a broad and less critics-oriented overview of transfer research and its relevance in various applied domains.

Building on the evaluation of the transfer research history and the identification of existing conflicts between theories, the thesis culminates in the development of a novel, reconstructive theoretical account of transfer. This proposal will be aimed at resolving the disagreements and shortcomings

spotted beforehand. The published research included in this thesis eventually intends to support the claims made here and to provide some empirical evidence for their value and validity.

Finally, in Chapter 4, a brief summary of the main points is provided.

1.2 Diversity and unity of transfer theories

Any comparison and evaluation of different systems of beliefs, i.e., theories, is influenced by the degree of basic agreement on what phenomenon the theories are designated to explain, what kind of theoretical language they adopt for describing this phenomenon, and how well the postulations formulated in the respective language satisfies criteria of internal and external validity.

A major problem in psychology is that these three determinants are highly inter-dependent. Hence, it must first be stated what I see as the basic framework for the explanation of transfer. And having clarified that, it must be considered in what respects theories of transfer may differ and where they need to converge. Finally, the taken approach to comparing and evaluating theories is sketched out.

1.2.1 Mental representations as a common denominator in cognitive research

The majority of mental processes studied in research on human cognition have one thing in common: They all pertain in one way or another to the construction of mental representations. This is true, for instance, for perceiving, learning, problem-solving, reasoning and thinking, and recalling, as much as it is true for the phenomenon of *transfer*. Perception concerns the organism's effort to select and process sensory information to be integrated in mental representations; learning concerns the change and development in representations along experiential trajectories; problem-solving, reasoning, and thinking, in general, involve the goal-oriented modification and enhancements of mental representations; and recall deals with the memory-based reconstruction of mental representation. Transfer, finally, refers generally to the *relation,* and specifically to what I would call *concordance* between mental representations. The present thesis essentially tries to theoretically build on and elaborate, as well as empirically substantiate, this view taken on transfer.

Accepting what is being said in the opening statement, it follows that all of the mentioned phenomena must in their own way obey to or be influenced by the same underlying psychological principles and cognitive mechanisms. It also means that all of these phenomena must to a large degree be describable and explainable using the very same theory language, and applying the same empirical concepts, namely those related to the construction of mental representations.

Hence, by engaging in the study of transfer, we inevitably engage in the study of mental representations and their cognitive genesis. The logical duties of this thesis are therefore (a) to resolve the question of what kind of concepts we need to describe and explain the nature and construction of mental representations and (b) to scrutinize the value of these concepts in attaining an improved understanding of the phenomenon of transfer and its relation to other cognitive processes.

1.2.2 Distinct but not incongruous

Let us continue with another presumption. Regardless of the variety of approaches discussed in this thesis, in the end transfer can not mean different things even if research done under different headers and in separate domains may suggest this. Hence, we must ultimately seek a unanimous understanding of transfer emerging from a unified theory. And in order to recognize the space of phenomena and viewpoints that this unified theory needs to cover and consolidate we need to engage in a widespread review of transfer theories guided by the different approaches delineated below.

In saying this, I also need to emphasize that the attainment of a unified view on transfer does not mean that there can be only one single set of theoretical concepts applied to its research. As the study of human functioning is essentially multilayered, also the research of the various psychological phenomena and processes needs to use distinct concepts suitable to explain their diverse facets. A context-oriented organizational psychologist naturally pays attention to aspects of transfer that are different from those of a neuroscientist interested in activation potentials in different brain areas. As a consequence of this their tool box of theoretical concept and empirical paradigms might differ considerably. Yet, however different the languages used in these separate fields and focuses of research, they all must validly emerge from and relate to the same conception of transfer, i.e., they cannot be contradictive in their implications. The core attention of the stance taken in the current thesis lies with higher cognition, such as human thinking and understanding. Hence, to the extent that the science of psychology is seen as engaging in the study of human mentality the presented thesis of transfer needs to be authoritative.

1.2.3 Reconstruction starts from review and aims at resolution

Most discussions of transfer to date can be developed from the same operational definition, describing it as the process and the effective extent to which past experiences (also referred to as *transfer source*) affect learning and performance in a present novel situation (*transfer target*) (Ellis, 1965; Woodworth, 1938). This, however, is usually also where the general consensus between various research approaches ends.

An ordered review of transfer research augmented with a close look at paradigmatic differences and similarities between them will supply the reader

with assorted insights into the historical foundation of theorizing about the phenomenon. The key constructs and ideas related to transfer research, for instance, within the different domains will be sorted out and linked at the same time. Since a considerable body of the research on transfer is trans-disciplinary or done with concepts that penetrate the borders between domains, the ordering of concepts under different domain headings, or for that matter the categorical separation of the domains themselves, is intricate and may at times appear arbitrary. As with all categorical distinctions, they are conceptually debatable, and of analytical value only in so far as their analytical purpose is not conceptually reinterpreted and misunderstood.

Obviously, the greatest bulk of theoretical and empirical research published in recent times has been done on transfer of *cognitive skills* and knowledge, for example with regard to problem-solving and analogical reasoning (Gentner & Gentner, 1983; Gick & Holyoak, 1980, 1983; Holland, Holyoak, Nisbett, & Thagard, 1986; Robertson, 2001). I judge it therefore as important to include explicit references to so called "non-cognitive" accounts of transfer, in order to counterweigh the omnipresent narrow cognitive view. This is why this thesis explicitly reserves sections for socio-emotional and motor dimensions of transfer (see Sections 2.3.1 and 2.3.2). The cognitive approach to transfer, on the other hand is apparent throughout the various review sections, and the key target of the proposed reconstructed theory.

The first goal of reconstruction must be to mark and trace the roots of the overarching transfer principles under discussion. Key concepts must be extracted from various transfer models and their inter-relation and contribution to research progress evaluated. Novel concepts must be introduced in the cases of conflicts or inadequacy with regard to the explanation of transfer.

2 REVIEW OF TRANSFER RESEARCH

There are a wide variety of viewpoints taken on transfer; and therefore research can and must be reviewed from many different perspectives. In doing so I shall (a) employ a taxonomical approach that usually intends to categorize transfer into different types; (b) adopt an application domain-driven approach by focusing on developments and contributions of different disciplines that have traditionally been interested in transfer; (c) examine the psychological scope of transfer models with respect to the psychological functions or faculties that are being regarded. This will lay out the foundations for the proposal of a concept-driven classification at the beginning of Chapter 3, which reveals the relationships between theoretical and empirical traditions.

2.1 Transfer taxonomies

Of the various attempts to delineate transfer, typological and taxonomical approaches belong to the more common ones (see, e.g., Barnett & Ceci, 2002; Butterfield, 1988; Detterman, 1993; Gagné, 1977; Reeves & Weisberg, 1994; Salomon & Perkins, 1989; Singley & Anderson, 1989). I will therefore start with looking into their approaches and contribution first. This will essentially provide some background and contextual knowledge as well as the necessary terminology for the subsequent reviews.

2.1.1 The many faces and labels of transfer

Transfer has been given a wide variety of tags. These refer to the multiplicity of conditions, processes, and effects that research has been focusing on. The most common distincitions and their labeling will be discussed in the following.

The effect-driven perspective: Positive versus negative transfer

Starting by looking at the effect side of transfer, i.e., in terms of the common performance criteria, speed and accuracy, transfer theories distinguish between two broad classes of transfer that underlie all other classifications: *negative* and *positive* transfer. Intuitively negative transfer could be understood as failure to transfer past learning experience to a novel task and situation, where previously acquired knowledge and skills could, in fact, be effectively used to facilitate learning and performance (i.e., failure as simple absence of positive transfer). Instead, negative transfer refers to the impairment of current learning and performance due to the application of non-adaptive or inappropriate information or behaviour. Negative transfer is therefore a type of interference effect of prior experience causing a slow-down in learning, completion or solving of a new task when compared to the performance of a hypothetical control group with no respective prior experience.

The situation-driven perspective

However, to be arguing for the psychological case of "trans-ferrere" (Latin for "carrying over") we need to have more than just a measure of its effects. In reference to the earlier noted operational definition of transfer, we need an understanding of what is meant by experiences, by affecting, and by novel situation. Let us start by considering the latter.

Since no two instances in life can occur simultaneously in time nor be identical, the notion of novelty of a situation per se is worthless without specifying the degree of novelty in relation to something that existed before. Butterfield and Nelson (1991), for example, distinguish between *within-task*, *across-task*, and *inventive transfer*. While this categorization seems at first appealing, it also conveys some typical problems and challenges. For instance, if transfer is to a task or situation, which is so similar to a previously experienced one that it actually can be considered as the same task (i.e., within-task transfer), then how do we distinguish transfer from learning in general? The corresponding deliberation is that learning refers to mental processes involved in the course of a repeated confrontation with a certain type of task or situation, of which the single accounts can never be identical. Butterfield and Nelson have themselves not been blind to this argument, but they still refrain from equating learning and transfer as proposed by Salomon and Perkins (1989, p. 115).

Across-task transfer, according to Butterfield and Nelson's (1991) model refers to the application of a learned principle in a new task situation which is superficially different, yet functionally equivalent to the prior one. Inventive transfer, finally, is used to describe incidences where learners can not make use of the same solution principles previously learned, but have to develop a new solution on the grounds of similarities and critical differences of source and target task. Understandably, Butterfield and Nelson pose the question to whether this should be rather characterized as problem-solving than transfer.

With two of the three transfer types identified by Butterfield and Nelson (1991) being questionable instances of transfer, the taxonomy serves equally well to exemplify the problems related to defining transfer than it adds to its clarification. Butterfield and Nelson, however, believe that a more sophisticated taxonomy, i.e., one of finer diversification or greater inclusiveness, would suggest a conceptual clarity that lacks theoretical and empirical justification.

Indeed, this argument appears very valid with regard to Haskell's (2001) taxonomy for instance, which proposes a gradual scheme of similarity between tasks and situations. It distinguishes between *non-specific transfer* (i.e., the constructivist idea that all learning builds on present knowledge), *application transfer* (i.e., the retrieval and use of knowledge on a previously learned task), *context transfer* (actually meaning context-*free* transfer between similar tasks), *near* versus *far transfer,* and finally *displacement* or *creative transfer* (i.e., an inventive or analytic type of transfer that refers to the creation of a new solution during problem solving as a result of a synthesis of past and current learning experiences). Both, near and far transfer, are "spongy", yet they are widely used terms in the literature. The former refers to transfer of learning when task and/or context change slightly but remain largely similar, the latter to the application of learning experiences to related but largely dissimilar problems. Far transfer can also be considered as the prototypical type of transfer, and it is closely related to the study of analogical reasoning (see also Barnett & Ceci, 2002, for a taxonomy of far transfer).

The key problem with Haskell's (2001) transfer taxonomy is that it offers an excessive number of labels for different types of transfer without really engaging in a discussion of the underlying concepts that would justify their distinction, i.e., *similarity* and *the nature of transferred information*. This makes it very difficult to appreciate the internal validity of the model.

Two broad underlying dimensions: Where and when versus what and how

For our current purposes, Haskell's (2001) and Butterfield and Nelson's (1991) taxonomies serve well in reemphasizing two characteristic types of dimensions in transfer theories. The first type of dimension usually denotes the hypothesized relation between transfer source and target (e.g., within-task vs. across task; similar situations vs. different situations; example-to-principle and vice versa; simple-to-complex and vice versa etc.). The second type expresses some rudimentary conceptualization of what transfer is and how transferred information is applied or adapted (i.e., how transfer itself works).

The issues related to the first dimension reappear in nearly all transfer taxonomies in the form of distinctions made along the *specific*-versus-*general* dimension. Mayer and Wittrock (1996, pp. 49ff.), for instance, discuss transfer under the labels of "general transfer of general skill" (e.g., "Formal Discipline", e.g., Binet, 1899), "specific transfer of specific skill" (e.g., Thorndike's, 1924a, b, "identical elements" theory), "specific transfer of general skill" (e.g., Gestaltists' transfer theory, see origins with Judd, 1908), and "meta-cognitive control of

general and specific skills" as a sort of combination of the previous three views (see, e.g., Brown, 1989).

In fact, the specific-versus-general dimension applies to all transfer types, no matter whether the focus lies on the relation between source and target (i.e., from where to where is transferred), or on the transfer itself (i.e., what is transferred and how). Within the problem-solving literature the distinction between specific and general methods is made mostly with reference to Newell and Simon's (1972) strong versus weak problem solving methods (Chi, Glaser & Farr, 1988; Ericsson & Smith, 1991; Singley & Anderson, 1989; Sternberg & Frensch, 1991).

This brings us to the second type of dimension underlying transfer taxonomies. *Reproductive* versus *productive* transfer (see Robertson, 2001) are good examples of opposite poles of this dimension. Whereas reproductive transfer refers to the simple application of knowledge to a novel task, productive transfer implies adaptation, i.e. mutation and enhancement, of retained information. A similar dichotomous distinction is the one between *knowledge transfer* and *problem-solving transfer* (Mayer & Wittrock, 1996). Knowledge transfer takes place when knowing something after learning task 'A' facilitates or interferes with the learning process or performance in task 'B'. Knowledge used is referred to by many different terms such as declarative or procedural types (Anderson, 1976), but it means for our purposes that there are representational elements that suit 'A' and 'B'. Problem solving transfer, on the other hand, is described as somewhat more "fluid knowledge" transfer, so that experience in solving a problem 'A' helps finding a solution to problem 'B'. This can mean that the two problems share little in terms of specific declarative knowledge entities or procedures, but call for a similar approach, or solution search strategies (e.g., heuristics and problem solving methods). A reasonably broad formulation for our purposes states that having represented 'A' facilitates the representation of 'B'. The issues discussed in problem-solving transfer literature are also closely related to the concepts of strategic and theoretic transfer (Haskell, 2001, p. 31), and cognitive research on analogical reasoning, rule-based thinking and meta-cognition (see Section 2.3.3 for a more detailed discussion).

Another concern that is frequently addressed in transfer taxonomies is the question of conscious effort. *High-road* vs. *low-road transfer* (Mayer & Wittrock, 1996; Salomon & Perkins, 1989) expresses a distinction between such instances of transfer where active retrieval, mapping and inference processes take place, as opposed to those instances that occur rather spontaneously or automatically. Hence, low-road transfer concerns frequently employed mental representations and automated, proceduralized knowledge, and occurs preferably in near transfer settings. In contrast, high-road transfer is more conception-driven and requires cognitive and meta-cognitive effort.

2.1.2 Discussing the contribution of taxonomy-oriented review

It is not easy to readily assign a general contributory value to historic transfer taxonomies because they have commonly not been developed in a reconstructive spirit. Their main aim has usually been the proposal of a cartography of transfer research and its conditions, which often leads to the segmentation of transfer research and theory, rather than to their sophistication. In the context of the current thesis, transfer taxonomies provide us with necessary terminological awareness to appreciate further reviews, but it also demonstrates the problems related to the enormous terminological multiplicity.

Few typological distinctions are based on some assumed inherent logic of the transfer process; usually they are induced from superficial perceptions. Instead of targeting real questions about the nature of transfer, researchers' approaches have frequently been to split the phenomenon into various types that readily translate into different experimental conditions. Evidently, there is potential value in doing so and indeed transfer situations and an individual's actual cognition may vary significantly between different transfer settings. However, taxonomical distinctions have the tendency to complicate or even obstruct subsequent reintegration of the findings on transfer into a more profound understanding of the phenomenon, and thus impair scientific progress in revealing the actual psychological processes involved.

It is nevertheless fair to notice that in the course of this thesis I will myself propose a type of taxonomy of transfer research that is based on its underlying theoretical concepts and empirical paradigms. This will serve as a preparative step in reconstructing and consolidating cognitive transfer. In consciousness of this fact, presently available taxonomies need to be valued for their potential to uncover common areas of debate as well as tacit dimensions and perspectives underlying the various conceptions.

Learning and similarity

Two important themes that have become evident so far are the relationship between transfer and learning and the idea of similarity. The two discussions are innately linked to each other because the distinction of transfer from learning is usually done with reference to a cut-off point on the similarity dimensions, by which the relation between a current and a past situation is estimated. The more similar two situations are rated, the more probable it becomes that any witnessed improvement in performance is due to learning rather than to transfer. The same logic is true in the other direction of the transfer-learning dimension.

The discussion on the dissimilarity-similarity distinction has the ambivalent character of being conducted in reference to a dimensional or polar conception and dichotomous model interchangeably. Hence, learning is usually implicitly awarded its own place at the periphery of transfer taxonomies that are based on near-far distinctions. And this raises the question whether it would not be sounder to concentrate more intensively on the common cognitive

bases of learning and transfer, than on some conceptual distinction between them.

Conceptional approaches to similarity are themselves of very heterogeneous nature and have subsequently been applied in rather different degrees of rigor to transfer taxonomies. Sources of similarity assessment as used in transfer taxonomies have traditionally been concrete stimuli, context and knowledge domain, and psychological task. Taxonomies do usually not contribute much to the question about the cognitive nature of similarity; a concern that has only really emerged in the context of research on analogical reasoning (see Section 2.3.3).

To summarize: Apart from the effect-based distinction between negative and positive transfer, taxonomies have largely been constructed along two, mostly tacit, dimensions. One concerns the predicted relationship between the primary and secondary learning situation in terms of categorical overlap of features and knowledge specificity constraints. The other concerns some general assumptions about how transfer relationships are established, in terms of mental effort and cognitive process. Taxonomies have traditionally been less concerned with labelling the actual vehicle of transfer, i.e., what is the explanatory mental unit of transfer that is carried over. This is also one reason why the distinction between negative and positive transfer has not been related to actual mental process issues in the context of transfer taxonomies, but mainly been explained within the redundant framework of near-versus-far transfer.

2.2 Traditional fields of transfer research

Obviously, there are a nearly unlimited number of research fields that share some applied interest into the study of transfer, as it pertains to learning in general. For the present review I have chosen three research areas that have to my opinion contributed in very substantial ways to the progress of transfer research, both from a conception and empirical point of view. These are the fields of *education science*, *linguistics*, and *human-computer interaction (HCI)*. In fact, most transfer research has been conducted in reference to one of these applied settings, rather than in basic cognitive psychological laboratory conditions.

2.2.1 Educational psychology: Teaching for transfer

Due to their core concern with learning, educational science and practice are the classic fields of interest regarding transfer research, and probably the prime target for the application of theories. In fact, transfer of learning represents much of the very basis of the educational purpose itself. What is learned inside one classroom about a certain subject should aid in the attainment of related goals in other classroom settings, and beyond that it should be applicable to the student's developmental tasks outside the school. Indeed, the need for transfer

becomes more accentuated. This is because the world educators teach in today is different from the world they themselves experienced as students, and differs equally from the one their students will have to cope with in future.

Teaching for transfer

By nature of their applied interest, educationalists' main concern has been less with the question of *how* transfer takes place, and much more with *under what conditions,* or, *that* it happens at all. Obviously, the basic conviction that student's learning and achievement levels depend primarily on learning and achievement prerequisites, has constituted a central part in educational learning theories for quite some time (Gage & Berliner, 1983; Glaser, 1984). The major focus in educational transfer studies has therefore been on what kind of initial learning enables subsequent transfer.

"*Teaching for transfer*" through the selection and promotion of specific teaching contents, instructional methods, and learning strategies has proved vital with educators, at least since the inception of Herbartian pedagogical thinking. In addition to the diachronic and trans-contextual perspective this is essentially true also with respect to the inter-individual differences in learning as a subjective and proactive build-up process of cognitive structures. Hence, teachers are concerned with the effects of learning on transfer, as well as the role of transfer *for* learning. And, as noted in the discussion of transfer taxonomies, we need to question again the theoretical separation of learning and transfer.

From Formal Discipline to meta-cognition

Educational transfer paradigms have been changing quite radically over the last one hundred years. According to the doctrinarian beliefs of the *Formal Discipline* (Binet, 1899*)* transfer was initially viewed as a kind of global spread of capabilities accomplished by training basic mental faculties (e.g., logic, attention, memory) in the exercise of suitable subjects like Latin or Geometry. With the turn of the 20th century, learning, and therefore also transfer of learning, was increasingly captured in behavioural and empiricist terms, as in the Connectionist and Associationist theories of Thorndike (e.g., 1932), Guthrie (e.g., 1935), Hull (e.g., 1943), and Skinner (e.g., 1938). Thorndike (1923, 1924a and b) attacked the Formal Discipline empirically and theoretically and introduced the theory of "identical elements", which is probably still today the most influential conception about transfer (Thorndike, 1906; Thorndike & Woodworth, 1901a, b and c). Thorndike's belief that transfer of learning occurs when learning source and learning target share common stimulus-response elements, prompted calls for a hierarchical curricular structure in education. "Lower" and specific skills should be learned before more complex skills, which were presumed to consist largely of configuration of basic skills. This small-to-large learning also referred to as *part*-to-*whole* or *vertical transfer* has been popular with theories of learning hierarchies (Gagné, 1968).

It has later been challenged from conceptualistic point of views, which argue that learning is not just an accumulation of pieces of knowledge (i.e., rote memorization), but rather a process and product of active construction of cognitive knowledge structures (Bruner, 1986; Bruner, Goodnow & Austin, 1956). Knowledge, from a constructivist perspective, was no more believed to be a simple *transfer by generalization* to all kinds of situations and tasks that contain similar components (i.e., stimulus-response patterns; see also Logan, 1988; Meyers & Fisk, 1987; Osgood, 1949; Pavlov, 1927).

The critical issue, subsequently, was the identification of similarities in general principles and concepts behind the facades of two dissimilar problems, i.e., *transfer by insight*. This idea became popular in the Gestaltists' view on transfer (e.g., Katona, 1940), and, in combination with growing interest in learners as self activated problem-solvers (Bruner, 1986), encouraged the search for abstract problem-solving methods and mental *schemata*, which serve as analogy enhancing transfer-bridges between different task situations.

Emerging from these developments a new theme started to dominate educationalists' research in transfer: *meta-cognition* (Brown, 1978; Brown & Campione, 1981; Campione & Brown, 1987; Flavell, 1976). In contrast to classical knowledge forms like declarative and procedural knowledge, different types of meta-knowledge and meta-cognitive skills such as strategic knowledge, heuristics, self-monitoring skills and self-regulation became quickly the royal road to learning and transfer. Characterized as self-conscious management and organization of acquired knowledge (Brown, 1987) it is evident that meta-cognitive awareness of task features, problem structures, and solution methods makes relations between different situations cognitively salient: Only an individual who learns from learning, learns for future learning. Soini (1999) developed on the same core ideas an examination of the preconditions for active transfer. Her emphasis is on the active and self-reflected management of knowledge to increase its accessibility.

Just as low-road and high-road transfer are used to denote automated and reasoning-based transfer respectively (Mayer & Wittrock, 1996), meta-cognitive transfer may then be portrayed as "satellite" transfer. To some researchers, meta-cognition and transfer have become so entangled that the argument was generated that only the measurement of positive transfer effects truly supports inferences that meta-cognitive learning has taken place (e.g. MacLeod, Butler & Syer, 1996).

The generality predicament

Ever since the introduction of the meta-knowledge theme in education science, transfer discussions have been oscillating between the position taken by those representing the meta-cognitive view, and those who stress that generic knowledge forms alone do not allow an effective transfer of learning: When knowledge stays "on the tip of the tongue", just knowing that one knows a solution to a problem, without being able to transfer specific declarative knowledge (i.e., know-what) or automated procedural knowledge (i.e., know-

how), does not suffice. In support of this argument, it was found that a person with extensive training experiences in examples, and a large related knowledge store may often perform better in transfer problems than a person who readily grasps where to map a problem to and who understands the required transfer strategies, but does not have sufficient specific experience (Brown, 1990; Mayer, 1989). As Haskell (2001, p. 99) puts it "this is largely the case because without an extensive knowledge base, there is nothing to connect isolated strategies together", and because meta-cognition based transfer only imposes a great load on working memory (Sweller, Merriënboer & Paas, 1998).

Another blow to the meta-cognitive view has been that spontaneous transfer has generally been hard to demonstrate in empirical settings. Reports of successful transfer usually range around twenty percent of participants (Cormier & Hagman, 1987; Detterman, 1993). Understandably some researchers began to specifically investigate why transfer is so readily being presumed as part of every day learning, yet so difficult to model and to experimentally prove in instructional settings (e.g. Brown, 1989).

Specifically weak has been empirical support for so called far transfer (Royer, 1979), which would be the ideal demonstration of mental abstraction and meta-cognitive processes, as well as of key relevance for educational purposes because it traverses classic knowledge domains (Clark & Blake, 1997). Indeed, I would argue that richly interconnected and meta-cognitively regulated mental representations dilute the notions of domain-*specificity* and near-versus-far transfer. This is because what was separated in different knowledge domains merges mentally into the same meta-domain, i.e., through structural inter-connection and integration on a higher hierarchical level of abstraction, or by conceptual tuning and combination. Thus in meta-cognitive transfer, "far" becomes "near", and specific general. Accordingly, Clark and Blake (1997) promote the specific training of cognitive processes that promote far transfer, i.e., self-regulated learning and meta-cognitive control (see also Corno & Mandinach, 1983). Obviously, this viewpoint is nothing but a new version of the Formal Discipline idea, and similar to Mayer and Wittrock's (1996) belief about enhancing transfer through "improving the mind". Teaching programs based on this view, such as LOGO, have, however, not been able to foster general intellectual abilities and transfer skill the way it was hoped (e.g., Dalbey & Linn, 1985; Pea & Kurland, 1984).

Return to the specificity view

Another emerging view on teaching for transfer started was to teach by and through transfer. This means that teaching itself should whenever and wherever possible model transfer to the learner, and therefore continuously support the individual effort of connecting present learning to the personal knowledge base (e.g., mastery learning and adaptive learning techniques). And, because structures and processes alone are rather volatile without a concrete and substantive knowledge base, teaching should provide extensive experiences with multiple and contextually altered examples, both within a

specific domain as well as in its periphery; a view that is also supported by results about learning in hypertext environments (e.g., Jacobson & Spiro, 1995). This ongoing and manifold instructive modelling and elaboration on when, how and why certain strategies are used, should allow for meta-cognitive tuning and restructuring to take place during initial training; and thus is thought to reduce cognitive load and contextual interferences during transfer (de Crook, van Merriënboer & Paas, 1998; Sweller et al., 1998).

Specific teaching of the cognitive and behavioural requisites for transfer marked in principle a return to the identical element view, and can be summarized with Dettermann's (1993) conclusion that transfer does not substantially go beyond the restricted boundaries of what has been specifically taught and learned. It, thus, appears that the basic transfer paradigms in educational psychology keep replicating themselves. And fundamental promotion of transfer itself is seen to be achievable through sensibilization of students by creating a general culture and "a spirit of transfer" inside the classroom on the one hand, and by allowing concrete learning from transfer models on the other (Haskell, 2001).

2.2.2 Inter-language transfer

Another traditional field of applied research is inter-language transfer. Here the central questions were (a) how does learning one language L_1 (or more generally: $language_m$) facilitate or interfere (Weinreich, 1953) with the acquisition of and proficiency in a second language L_2 ($language_{n>m}$), and (b) how does the training and use of L_2, in turn, affect L_1. Several variations of this conception of inter-language transfer can be found in the literature, also referred to as mother tongue influence or cross language interference (Corder, 1983, 1994; Faerch & Kasper, 1987; Jiang & Kuehn, 2001; Odlin, 1989; O'Malley and Chamot, 1990).

Continuous transfer within language use

What makes inter-language transfer a complex but at the same time very valuable research matter is the fact that language knowledge skills continuously develop. This is so for L_1 as well as for L_2, when only bilingualism is considered, while alternately at least one of them is also continuously in use. This has led to the development of very different models of how languages are mentally represented and managed, with L_1 and L_2 seen (a) as two independent or autonomous mental systems (e.g. Genesee, 1989; Grosjean, 1989), (b) as being represented in a single unified system (e.g. Redlinger & Park, 1980; Swain, 1977), and (c) as rooting in a common underlying, multi-lingual conceptual base (CUCB; see Kecskes & Papp, 2000).

What Kecskes and Papp (2000) call the CUCB and CAIS (i.e., Constantly Available Interacting Systems of the two language channels L_1 and L_2) has been visually phrased by Cummins (1991) into the metaphor of two icebergs (L_1 and L_2) which appear separate in use (i.e., on the cognitive surface) but are unified

beneath the surface and represented by the same central processing or operating system (see also Baker, 1996). This model allows for inter-language transfer to be viewed either as permanent, possibly bidirectional interaction between L_1 and L_2 through the CAIS, or in terms of a continuous change in the CUCB that affects both language channels, as an effect of the use of one of them.

Kesckes and Papp (2000) continue this line of argument by explicating that anyone acquiring a second language, will as of principle cease to be a pure native speaker in his or her mother tongue, nor will such an individual ever achieve natural proficiency in the foreign language (see also Cook's, 1992, multi-competence theory). And as an implication of this one needs to question the appropriateness of the transfer (i.e., carry over) metaphor itself in studying inter-language effects. If there is not one set of mentally processed information being carried over or affecting another instance of information processing, but if it is the whole of the past experiences providing the framework for current experiences and behaviour, we must once again ask what the transfer concept adds to the concept of learning, or whether it is at all separable from it.

Lexical and other elements

Another important contribution of inter-language research to the study of transfer lies with its debate about relevant cognitive constituents. Empirically transfer has been demonstrated best through superficial elements like lexical items, negation forms, and word order, but also semantic differences, and relative clauses (see Powell, 1998). This prevalent focus on superficial $L_1 \rightarrow L_2$ transfer, i.e., in terms of the interference effects and wrong application of lexical items and grammatical forms, has supported the negative transfer stigma in second language learning, especially during the initial learning stages. Superficial transfer is further believed to be typical for beginners in a novel language, because no really *common* underlying conceptual base (CUCB) has yet been developed; rather the concept base of L_1 serves as substitute for such a shared representational system. Additional grounds for distinguishing language learning and inter-language transfer effects at early stages of L_2 proficiency from later stages are also provided by the *threshold hypothesis* of language achievement (Toukomaa & Skutnabb-Kangas, 1977).

Concepts and use

Consistent with his proposed model, Cummins (1989, 1991) argued that it is mainly conceptual knowledge, as opposed to specific linguistic elements, which is transferred from one language to another. This view is shared by Odlin (1989) who criticizes the overemphasis on morphology and syntax, and Kecskes and Papp (2000) who miss the consideration of language use and cultural embedment next to the classical focus on grammar and structural phenomena in inter-language transfer (see also O'Malley & Chamot, 1990). Kecskes and Papp also add an important clarification, according to which the simple use of a foreign word or speech production concept in the mother tongue, or vice versa,

is not a real case of inter-language transfer. Transfer is to be seen as a more "painful" attempt of "neutralizing" knowledge and skill when creating a representation in the CUCB, so that it can be re-encoded into an equivalent or analogue language codes and concepts of the alternate language channel (p. 50ff.).

In a way very similar to the contextual interference hypothesis discussed earlier, Kecskes and Papp (2000) believe finally that the development of the CUCB, and the process of second language attainment, are both slowed down and more complex in nature, when the two socio-cultural contexts of the languages differ markedly. Later proficiency and positive inter-language transfer, however, become enhanced. Here from profits not only L_2 but essentially also the development of knowledge and manipulation skills in L_1 (see also Ben-Zeev, 1977; Collier & Thomas, 1992; Riccardelli, 1992). On the other hand, where languages are historically and linguistically closely related to each other, the positive effects of transfer may be more obvious, calling only for caution with respect to *overuse* of familiar linguistic forms. But caution is also needed regarding limitations on the use of familiar forms, since this might lead to (error) avoidance and restrictions in transfer, learning and performance (e.g. Flyman, 1997; Kellerman, 1991).

Conceptual base

A series of studies in second language teaching and learning seem to support the above outlined models of Common Underlying Proficiency (CUP) or CUCB, and actually demonstrate success in promoting positive transfer (Cummins, 1979, 1984; Jiang, & Kuehn, 2001; Kecskes & Papp, 2000; O'Malley & Chamot, 1990). There is, however, also ample evidence for different kinds of mistakes that learners should not have made given the similarity of L_1 and L_2 (LoCoco, 1975; Richards, 1971). Frequently it is also difficult to validly distinguish between transfer effects attributed to the hypothesized CUCB and other general cognitive factors, such as personality, intelligence, and motivation contrasting with them.

Another important development for the research in language transfer was the birth of the "*Interlanguage*" concept (Corder, 1967; Nemser, 1971; Selinker, 1972). This refers both to the mechanisms of inter-language transfer as to the basic learning strategy in second language acquisition. Its formation is understood much like that of the CUCB, in terms of an evolvement of a largely autonomous system and linguistic forms, which are neither part of the native language nor the target language. While learning a second language, the individual is believed to move along an Interlanguage continuum between the native language and the target language (Selinker, 1972). In the course of this process the learner continuously makes and tests hypotheses about the target language, which become then cases of transfer. The *transitional competence* for generating these hypotheses is based on knowledge about language in general, gained from L_1, and the improvements in L_2.

Truly successful students make the journey to a high level of competency in the target language, but in general students become "fossilized" somewhere along the Interlanguage dimension (Brown, 1993). They make the same mistakes over and over, against their better foreign language knowledge. Such persistent negative transfer is explained by the fact that certain linguistic items, rules, and concepts are carved into the Interlanguage as an effect of initial experiences in one's native tongue. Leung (1998) develops this idea even further to discuss the transfer *between two Interlanguages*.

Contrastive analysis

Another comprehensive model that tried to answer the question about transfer processes involved in the transition from monolingual to bilingual, was the hypothesis of *contrastive analysis* (Fries, 1945; Lado, 1957). Contrastive analysis builds on the idea that a formed structural 'picture' of any language is put into comparison with the structural 'picture' of another language through the process of mapping one system onto another, and thus similarities and differences could be identified. Problematic areas are indicated by structural dissonance, possibly resulting in transfer interference from L_1 to L_2. In contrast, concordance between L_1 and L_2, suggests that acquisition would take place with little or no difficulty.

The generic view

Yet, although the notion of structure implied going beyond superficial objects, items, or predicates, the contrastive analysis theory worked largely within the framework of behaviourist, stimulus-elicited transfer. It was not until Chomsky (1957, 1959, 1961) that this superficial confinement was overcome, and the emphasis became more on rules and the generic structures in language understanding and production. In the opinion of Chomsky many of the structures and rules for the development of linguistic competence do not have to be learned, but rather form something like universal cognitive laws of language. According to him, the transfer "bridges" between two language systems consist largely of these innate organizational concepts in language (i.e., "universal grammar"). In addition to deep structural elements, Chomsky saw linguistic transfer as dependent on the number of shared comprehension and production rules, an idea that was later picked up by Faerch and Kasper (1987), and essentially developed into Singley and Anderson's (1985, 1988, 1989) cognitive transfer theory.

Finally, as mentioned, linguists have also become increasingly interested in $L_2 \rightarrow L_1$ transfer, which in turn is believed to be the result of an intensified and continuous exposure to L_2 and the resulting development of a CUCB. As a consequence, intensive exposure to a second language also promotes meta-linguistic awareness (Vygotsky, 1934/62), which is seen to foster performance through transfer in the same way as discussed for meta-cognitive skills in the

previous section on transfer in educational settings (e.g., Gass, 1983; Odlin, 1989; Sorace, 1985).

2.2.3 Human-Computer Interaction: Designing for transfer

A third research area that has produced a variety of transfer models and empirical results can be located within the field of Human-Computer Interaction (HCI). Indeed, with the start of the user age in the 1980s, HCI and all kinds of virtual environments have in many ways become something like psychological micro-worlds for cognitive research. This is naturally also reflected in the study of transfer.

Developments in favour of cognitive approaches to transfer research were especially accelerated by rapid changes in modern lifestyles, resulting in a virtual upsurge of cognitive demands in interaction with technology. Thus the call was on clearly domain-focused cognitive models to study the way users learn and perform when interacting with information technological systems (Card, Moran & Newell, 1980a and b, 1983; Olson & Olson, 1990; Payne & Green, 1986; Polson, 1987, 1988), which caused a blind spot with regard to the investigation of socio-emotional dimensions of transfer and cognition in general (see Section 2.3.2).

Another effect was that HCI- and HCI-based research actually created a novel transfer problem of its own: Can skill practised and performances measured in virtual experimental settings be validly transferred and generalized to real life environments? This problem is, for instance, immanent to all kinds of Intelligent Tutoring Systems (ITS) where task fidelity in the simulation environment has been identified as one of the key factors (Kenyon & Afenya, 1995; Kozak, Hancock, Arthur & Chrysler, 1993). Similar concerns quickly arose also with regard to the transfer from non-HCI experiences to the interaction with technology, as well as skill transfer from one HCI context to another.

Transfer based on the user complexity theory

Thorough investigations of cognitive skills involved in HCI tasks have their origins with the research on text editing (e.g., Kieras & Polson, 1982, 1985; Singley & Anderson, 1985). The offsprings of this type of research were computational cognitive models and architectures of various degrees of sophistication, suitable for all kinds of man-machine interaction studies, as well as studies outside of the HCI domain (see the section of cognitive transfer). The original examples for these have become Kieras and Polson's (1985) *user complexity* theory (later rephrased as c*ognitive complexity* theory) and the GOMS family (i.e., Goals, Operators, Methods, Selection rules) based on the Model Human Processor framework (Card et al., 1980a and b, 1983; John & Kieras, 1996a and b). All of these models have their roots in the basic principles of production systems and can be comprehended with the help of ends-means-

selections and IF-THEN-rules, combined with the necessary declarative and procedural knowledge (Anderson, 1995; Newell & Simon, 1972).

The crucial perspective for transfer became that of technology design. By applying cognitive models scientists and practitioners aimed at minimizing the amount and complexity of (new) knowledge necessary to understand and perform tasks on a device, without trading off too much utility value (Polson & Lewis, 1990). A key responsibility was hereby given to skill and knowledge transfer. And because the cognitive complexity theory is in fact a psychological theory of transfer applied to HCI (Bovair, Kieras, & Polson, 1990; Polson & Kieras, 1985), the central question was, how these models, united under the GOMS-umbrella, can be used to explain and predict transfer of learning.

The basic transfer-relevant assumptions of the emerging models were that production rules are cognitive units, that they are all equally difficult to learn, and that learned rules can be transferred to a new task without any cost. Because learning time for any task is seen as a function of the number of new rules that the user must learn, total learning time is directly reduced by inclusion of productions the user is already familiar with. Hence, the basic message of the cognitive complexity theory is to conceptualize and induce transfer from one system to another by function of shared production rules is, which is a new interpretation of Thorndike's (1923, 1924a and b) identical element premise and eventually echoed in Singley and Anderson's (1989) theory of transfer (Bovair et al., 1990; Kieras & Bovair, 1986; Polson & Kieras, 1985; Polson, Muncher & Engelbeck, 1986).

A practical implication of the procedural communality principle has been formulated by Lewis and Rieman (1993), who suggest something like "transfer of design" on the side of the industry: "You should find existing interfaces that work for users and then build ideas from those interfaces into your systems as much as practically and legally possible."

Critics regarding environmental validity

Nevertheless, GOMS models have never become widely applied by practitioners (Byrne, 2002; John & Kieras, 1996a and b). John and Kieras (1996b) further note that helping the user to acquire an appropriate representation of how the device works, rather than just supporting the build-up of procedural skills from the practice on examples, may substantially contribute to learnability. In another critique of the procedural communality paradigm, Karat, Boyes, Weisgerber and Schafer (1986) demonstrated that experienced users of word editors can be completely blocked from transfer to a different editor because of only one using procedure which they can not figure out. Thus, while production rules might be regarded as independent from each other, their execution and transfer certainly are not.

Other validity restrictions on the procedural transfer model in HCI settings have typically been identified as the directional specificity of production rules, the serial order of their execution, and the device-dependency (i.e., device-specificity) versus device-independency of knowledge. In general

this means that learning a task on text editor A after editor B does not yield the same transfer benefits as learning editor B after editor A, that there are transfer deficits if the order of procedural execution is rearranged, and that increasing the applicability of device-independent knowledge enhances transfer in general. Some of these constraints have been addressed in more comprehensive models by inclusion of general learning capabilities and analogical reasoning processes that eventually lead to routine cognitive skills (Rieman, Lewis, Young, & Polson, 1994).

Emergence of holistic views of use

Discouraged by the confined character of the GOMS-related transfer models many research groups began to import and advance new concepts such as schemata principles and general methods; a general development encouraged by the emerging cognitive approach to transfer that was also witnessed by other applied fields. Bhavnani and John (2000) analysed different computer applications and strived to identify such user strategies (i.e., general methods to perform a certain task) which generalize across three distinct computer domains (word processor, spreadsheet, and CAD). Their conclusive argument is that "strategy-conducive systems could facilitate the transfer of knowledge" (p. 338).

Other research groups' authors that assessed the questions about how people learn in interaction with information systems, evaluated the usefulness of *metaphors* and how these should be taken into consideration when designing for exploratory environments (e.g. Baecker, Grudin, Buxton, & Greenberg, 1995; Carroll & Mack, 1985, Condon, 1999).

As researchers became increasingly interested in the quality of a user's knowledge representation (e.g., Gott, Hall, Pokorny, Dibble, & Glaser, 1993), *mental models* and *adaptive expertise*, as knowledge and skills which generalizes across different contexts of complex problem- solving tasks, became of paramount concern (Gentner & Stevens, 1983; Gott, 1989; Kieras & Bovair, 1984). In contrast to the *knowledge of strategies* (Bhavnani & John, 2000), the accentuation shifted hereby towards *strategic knowledge* (Gott et al., 1993). Gott et al. demonstrated that surface similarities between different technical domains alone did not essentially facilitate transfer of learning because they limited the user's flexibility in the adaptation process. In accord with the ideas of schema-based and meta-cognitive transfer, the authors further formulated that "robust performance is one in which procedural steps are not just naked, rule-based actions, but instead are supported by explanations that perform like theories to enable adaptiveness" (p. 260). As noted, Soini (1999) developed a very similar view in her examination of the preconditions of active transfer.

Gott et al. (1993) finally note that mental models might be powerful instruments to analyse similarities between tasks as represented within a formulized cognitive architecture. However, they do not explain what particular similarities and dissimilarities are sufficiently salient from the individual's mental point of view to affect transfer of learning; nor can they

predict motivational or emotional conditions of transfer that are essential requisites for every learning process. This comment confirms the need for a reflective evaluation of the expressive capacity of different concepts in transfer research. And it also raises the question about the psychological scope of transfer, which shall be our next concern.

2.2.4 Discussion of the contribution of applied research

Because of the differing alliances in perspectives and contributions between the applied research fields, the discussion will first reiterate the pedagogic and HCI perspective, before considering the linguistic view points.

The pedagogic perspective

The pedagogic view point on transfer is exemplary in expressing the need for replacing the distinctive interpretation of the relationship between learning and transfer, with that of an inherent union. This is an important recurrent realization that will also be integrated into the general conceptualization of the phenomenon in the current thesis (see Section 3.2).

Indeed, transfer research in educational psychology has in nearly all respects been prototypical for the general development of concepts. This is also true for the debate staged around the specificity-generality and concreteness-abstractness distinctions between Thorndike (Thorndike, 1924a and b; Thorndike & Woodworth, 1901a, b, c) and Judd (1908, 1939), as well as for the ongoing quarrel between seeing transfer as a phenomenon of carry-over as opposed to general effects of mental practice and higher order cognitive control. Both themes have become of key relevance to cognitive transfer research to present date (see Section 2.3.3).

In spite of this, the dominating concern of studying pedagogically relevant transfer remained with applied teaching and curricular issues. Its research has not exerted the same amount of influence on basic research as for instance investigations in the field of HCI, whose contributions shall be reiterated next.

The user and design perspective

In analogy to the educational notion of "teaching for transfer" the idea of "*designing for transfer*" became a major driver for transfer-related research in the field of HCI. However, profiting from its close association with computational systems and the dominant information-processing metaphor in cognitive psychology, HCI research emerged as the main platform for the development of computational models of transfer within the framework of cognitive architectures. GOMS became the first elaborated application of the production system framework for modeling and predicting learning and transfer effects with users (Card et al., 1983); an approach that quickly found approval across the field (Kieras & Bovair, 1986; Singley & Anderson, 1989).

Nevertheless, the psychologically rich application of these models in actual use contexts also hinted at some potential limitations. In this it became clear that the conception of carried-over elements in terms of detached, independent, and purely syntax-oriented procedures may in application to actual learning and performance conditions prove insufficient to foster positive transfer. This generated increasing support within certain research groups for mindful conceptualizations of transfer. In consequence more efforts were dedicated to the investigation of forms and traits of mental representation as origin for transfer, instead of automated procedural elements (e.g., Gott et al., 1993).

The linguistic perspective

Inter-language transfer research has been less mainstream in terms of the prevalent concepts used. Naturally, the cognitive approach has here been equally influential as some of its pioneers, e.g., Chomsky or Vygotsky, have been active in the field of linguistics. This is easily apparent from the debate between exemplar-based, rule-based, and generative conceptions of learning, and their application to transfer (see also Section 2.3.2). Those concerns blend also well in with discussions on the role of specific examples, strategic knowledge, and metacognition presented in other fields of research (e.g., Brown, 1978; Gott et al., 1993). Additional and more unique contributions of inter-language research on transfer most therefore be located elsewhere.

Whereas the predominant conception of transfer in educational and HCI contexts has been emerging from the discrete source-to-target model and its conditional variations, inter-language transfer emphasizes the continuous, and cognitive innate nature of transfer. Language production and comprehension is seen inherently as an issue of ongoing transfer, or activation of conceptual hypotheses that may stem interchangeably from the learning and use experiences in language 1 or 2. The perspective on transfer transforms with this idea from one of comparison and carry-over between two mental entities (i.e., source and target), to one of seeing one situation through the lens of another, or on the basis of presently available mental constituents in general.

The reciprocal view on transfer source and target, as also expressed above, is another major contribution the research debate on inter-language transfer had to offer to transfer theorizing in general. Not only can past experiences influence present ones, but current activities can alter the quality of previously acquired skills and memories. Additionally, language transfer research has recalibrated the focus of transfer research from attending to the momentum of similarity to the investigation of differences between two languages. This led to interference-oriented research and increased attention towards *negative* transfer (see Corder, 1967).

Hence, the linguistic perspective reflects many of the major themes in theoretical development of transfer research, especially those concerning abstraction and generativity in learning. With regard to the basic conceptualization of the phenomenon in the current thesis, studies of inter-

language transfer also highlighted some other crucial aspects, such as the cognitive innateness and continuity of transfer, and the mixture of positive and negative effects (see Section 3.2).

2.3 Psychological scope of transfer research

As transfer pertains to the dependency of an individual's experience and behaviour on prior experience and behaviour, its research must involve all aspects of psychological functioning, ranging from physical activities, cognitive processes (e.g., thinking), emotion and connation, to its social and environmental dimensions.

Of course, when adopting a fundamentalist or holistic cognitive position it may be argued that all facets of transfer, including those pertaining to motor, affective, or social dimensions, can be reduced to some cognitive or even neural proxy, e.g., using approaches of cognitive neuroscience. This view has become very obvious with regard to the use of the skill concept in cognitive investigations in general, and transfer research in particular. Although the *cognitive* connotation of skill has largely emerged as the dominant conception, is not truly possible to appreciate the real meaning of skill without linking it to its motor or behavioural origins (Adams, 1987; Pear, 1927, 1948), and without extending its scope to include affective and social dimensions.

Therefore, on the level of actual behaviour, it is perfectly legitimate to differentiate between different kinds of psychological domains, resulting in distinct accentuations of transfer. These accentuations have partly also developed into specialized fields of research that shall be discussed in the following sections.

2.3.1 Motor transfer

Senso-motor skills are an essential ingredient in learning and performance in most tasks and can be categorized into continuous (e.g., tracking), discrete, or procedural movements (see Magill, 2004; Schmidt & Wrisberg, 2004, for recent basic overviews). Proceduralized motor skills have recently become the most referred to because they are consistent with the models of cognitive architectures (see Section 2.3.3) and because they are seen as relevant to nearly all physical interactions with the environment; as is the case in transfer situations as well.

Open-loop and closed-loop processes

Before the birth of the proceduralization concept, theories of motor learning have been influenced by the *open-loop* versus *closed loop system* distinction (Adams, 1971; Schmidt, 1975). The original formulation of the closed-loop view on motor performance and learning build on the momentum of internal

feedback from executed movements, which allow for error detection and adjustment of actions through the process of contrasting perceptual traces against memory representations (Adams, 1971). Motor learning was accordingly seen as dependent on repetition, accuracy, refinement, and synchronization of a series of called-up movement units (i.e., open-loop structures) that are regulated by closed-loop structures.

In response to this view a different open-loop perspective emerged, namely the one of motor programs (Schmidt, 1975). The learning of motor skills was hereby seen in terms of the build-up, modification, and strengthening of schematic relations among movement parameters and outcomes. This learning results in the construction "generalized motor programs" (i.e., a sequence or class of automated actions) that are triggered by associative stimuli, habit strengths, and re-enforcers, and can be executed without delay (Anderson, 1995; Schmidt, 1975, 1988).

Both theories have their origin with Thorndike's "Law of Effect", because the formation of motor behaviour is essentially dependent on knowledge of the outcome of the action taken. This is regardless of whether the essence of motor skills is seen with specific movements or parameters in a schematic motor program (Adams, 1971; Bartlett, 1947a and b, Schmidt, 1988).

The implications for transfer by adopting the motor schema and open-loop perspective converge with the assumptions of procedural transfer as assumed in the GOMS-related models (Card et al., 1983). This means that previously formed motor programs and their elements (i.e., parameters) transfer directly to other activities for which a rule or schema can be compiled of the same parameters, regardless of context (Schmidt, 1988). Consequently, there is little focus on issues of interference and limits of generalization in motor transfer, because procedural models commonly build on the momentum of highly automated and mutually independent representational units.

In contrast, Adams (1987) and a number of other researchers, raised specific questions about motor *interference*, separated into *proactive*, *retroactive* and *contextual* types (see overview in Magill & Hall, 1991). Similar to the research in inter-language learning, instances of negative transfer were recognized as cases where motor performance is suboptimal due to specific inhibiting effects of past learning on present behaviour (i.e., proactive), or of present learning on the reactivation of earlier acquired motor skills (i.e., retroactive), as well as interfering effects of contextual information on motor execution (e.g., Albaret & Thon, 1998; Jarus & Goverover, 1999).

Cognitive effort and elaboration

In accord with Sweller et al.'s (1998) contextual interference hypothesis, motor transfer is believed to be enhanced by conditions with high contextual complexity and variation during initial learning of a motor performance task. The explanation for this refers to the level of cognitive effort, resulting in a more elaborate representation of the learned skill compared to learning in low

interference conditions (Lee & Magill, 1983, 1985; Magill & Hall, 1991; Shea & Morgan, 1979; Shea & Zimny, 1983, 1988).

Likewise, a high degree of cognitive elaboration and knowledge about a motor task, combined with heightened self-monitoring and meta-cognitive awareness of task-demands, is seen to improve intentional transfer, especially due to the level of expertise (Ferrari, 1999). This is again especially true for transfer to novel environments and task domains. Such higher level of task functioning enables the learner to actively adapt to new problems and to altering contextual features (Bandura, 1969; Zimmerman, 1995).

Reviving classic paradigms

Another, classic theme that was revived in the literature on transfer of motor skill is the part-to-whole transfer of training (Adams, 1987, p. 51ff.; Thorndike, 1924a and b). It emerged, because it is nearly unconceivable to learn a highly complex motor task as a complete entity. Much like in curriculum research, positive generalization of skill units into coherent task situations has been very limited. Particularly it was found that initial whole-task performances after part-task training remains seriously impaired due to difficulties in the time-sharing of the activities. In consequence whole task training remains generally superior to the part-task-whole-task transfer approach of learning (Adams, 1987; Adams & Hufford, 1962; Briggs & Brodgen, 1954).

Finally, motor research provided some evidence for context- and task-independent savings in learning effort on a new task that seems to be explainable by heightened plasticity and functional reorganisation in the senso-motor neural network system. This is naturally in line with the formal discipline argument.

2.3.2 Socio-emotional dimensions of transfer

Motor and cognitive transfer are in many respects inseparable from issues of emotion and motivation, just as cognitive research in general must embrace affective dimensions of experience and behaviour (Barnes & Thagard, 1996; Thagard & Shelley, 2001). This basic awareness has a long tradition in psychology and, of course, in the philosophical works of Aristoteles, Descartes, and Hume, but has to date not been sufficiently regarded in cognitive research (Damasio, 1994; Leventhal & Scherer, 1987; Mandler, 1975; Oatley & Johnson-Laird, 1987; Rapaport, 1950; Scherer, 1995).

Assistant role of emotions in cognition

Naturally, emotions and especially motivation have always been closely linked to learning in educational psychology, but their role was generally conceptualized as more of an assistant or moderating nature, i.e., in facilitating versus hindering cognition (Bruner, 1960; Gudjons, 1999; Pea, 1987, 1988; Pintrich, Marx, & Boyle, 1993; Salomon & Perkins, 1989; Thorndike, 1932).

Approaches that focus on the same kind of relation between affect and transfer belong to the group that study main effects of affective beliefs on cognition in general, and in particular on transfer-relevant moderation and mediation effects of "will" on "skill" (see also Bong, 2002; Gist, Stevens, & Bavetta, 1991; Mathieu, Martineau, & Tannenbaum, 1993; Saks, 1995). In short: "Knowing how to solve problems and believing that you know how to solve problems are often dissonant" (Jonassen, 2000, p. 14).

Goal-attainment expression of emotions

In Holyoak's (1985) pragmatic transfer theory, emotion and motivation have been specifically linked to transfer through their relation to goal-achievement. Holyoak argued that transfer questions of analogical reasoning and mapping "can be fruitfully addressed only by taking account of goals of the cognitive system". Thus, emotional and motivational congruity versus discord is identified as a particular similarity constraint. Similarly, works on the interaction between mood and memory have demonstrated a dependency of learning and transfer processes on (a) the mood at initial training and encoding (i.e., primary learning) (e.g. Leight & Ellis, 1981), (b) the emotional state at time of transfer relevant memory retrieval (i.e., secondary learning) (e.g. Rholes, Riskind, & Lane, 1987), and (c) the emotional congruence between the two instances (Bower, 1981, 1987, 1992; Bower, Monteiro, & Gilligan, 1978).

Transfer of emotions

Emotional transfer must, however, also be regarded as a distinct aspect or type of transfer itself, i.e., one where the experiential relation between two situations is of affective nature (e.g., affective connotations and skills). It occurs wherever previously experienced feelings and attitudes toward a situation, object, or task are re-evoked in a current confrontation with related "symbols" (see Hobson & Patrick, 1995).

Figure 1 illustrates the different perspectives on socio-emotional transfer mentioned so far: (a) the influence of affect on cognition and vice versa; (b) the congruity of socio-emotional constraint factors during transfer; and (c) the carrying over of affective elements to a related current experience.

The preferred emotional transfer model to date has been the one of analogical inference, e.g., if you like product X, and product Y is similar to X, then you will probably like Y. Thagard and Shelley (2001) criticized the simplicity of analogical inference based on mere comparison of objects and properties and proposed a more complex model that accounts for structures of analogies, e.g., by including relations and causality structures. Their *emotional coherence theory* implemented this idea in the form of the HOTCO model (standing for "hot coherence") by drawing on assumptions made in preceding models, including *explanatory coherence* (ECHO), *conceptual coherence* (IMP), *analogical coherence* (ACME), and *deliberative coherence* (DECO) (see Thagard, 2000).

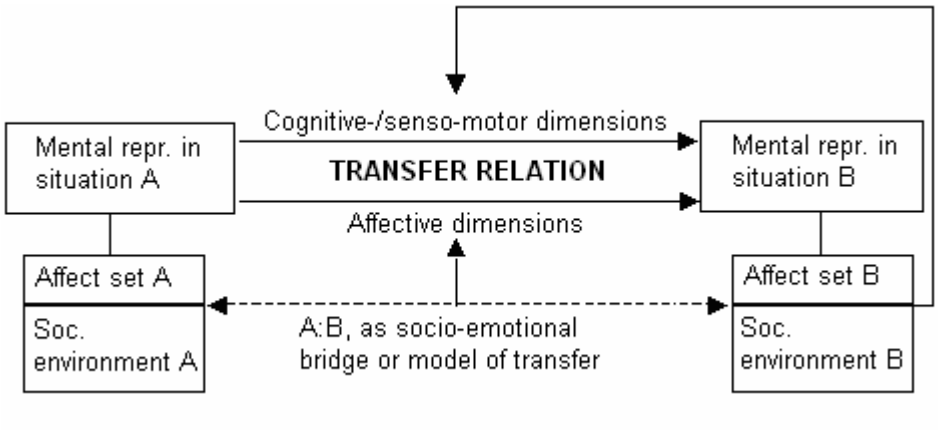

FIGURE 1 Basic model of the main effect and moderation roles of socio-emotional factors in transfer

Thagard, Eliasmith, Rusnock and Shelley (2002) define the emotional dimension of the coherence problem as consisting of the need to divide a set of elements (e.g., objects, concepts, procedures, goals) into ones that are accepted (i.e., of positive constraint relations with each other) and ones that are rejected (i.e., of negative constraint relations with the first group), and hereby creating "an emotional Gestalt that provides an overall "gut reaction" (see also Thagard & Verbeurgt, 1998). Hence, elements and relationships in cognitive structures are enhanced by accounting for emotional valences.

Persuasive behaviour, for instance, is believed to work on the principle of suggesting people to transfer the emotional valences of source elements to a new target. The trick is to create such a nexus between source and target that they are experienced by the people as coherent, sharing a relation of positive constraint. Communalities between this kind work and Gestaltists' *Prägnanz* concepts, or cognitive consistency concepts such as Heider's balance-model, or Festinger's dissonance theory are obvious (see Kiesler, 1969; Suedfeld, 1971).

The social dimension

There are naturally close links of the emotional coherence transfer theory to other similarity-based transfer phenomena in social cognition, e.g., categorization, stereotyping, illusory correlation, prejudice (e.g. Allport, 1956; Hamilton & Sherman, 1989, for a review on illusory correlation). In fact, transfer is in various respects intimately linked to the issues of classification performance, encoding strategies and categorization, because they all employ the momentum of grouping and relating situations in mental representation, and allow for the spread (i.e., transfer) of information between them (see also Wattenmaker, McQuaid & Schwertz, 1995; Zamani & Richard, 2000).

Another area of transfer research with social reference has been the generalization of social skills, trained in one context, to other contexts, with different social agents at present. The general implication of these kind of research findings has traditionally been the view of transfer as highly context-

dependent and situated (DuPaul & Eckert, 1994; Ninnes, Fuerst, Rutherford, & Glenn, 1991; Rutherford & Nelson, 1988).

Bandura's social-cognitive learning theory and other related social learning phenomena, such as *performance and learning anxiety* (e.g. Horwitz, 1986), *learned helplessness* (Miller & Seligman, 1975), *self-regulation* (Bandura, 1969; Schraw & Brooks, 1998; Zimmerman, 1995), and the *attribution theory of emotion and motivation* (Weiner, 1985) are all exceptionally fruitful for discussing both the emotional carry-over and the transfer-related effects of affective and volitional determinants on cognition and performance. In his self-efficacy theory Bandura (1977, 1986) provides explanations about how people construct current beliefs and motivations regarding problem-solving and performance demands by scanning previous experiences of mastery or failure in analogous situations. Comparison is made for shared sub-skills between the tasks, diagnostic, heuristic and meta-cognitive demands, and structural correspondence.

2.3.3 Cognitive transfer

The cognitive shift in psychology showed a great impact on the evolvement of new and refined concepts, methods, theories, and empirical data in transfer research, and it put the investigation of the phenomenon back on the general research agenda after a clear decline in relevant scientific publications between 1960 and the 80^{ies} (Cormier & Hagman, 1987; Haskell, 2001). Beyond the basic revitalization of interest in mentality, research on transfer has profited from two main drivers within the study of human cognition: These are the computational view and the intensified interests with the nature and quality of mental representations.

Analogy, metaphors, and the question of similarity

From the wide range of relevant concepts, research on *analogy,* in all its nuances, proved to be the most influential to the conceptualization of cognitive transfer. Indeed, many cognitive scientists, as well as road leading philosophers, consider analogy to be one if not the core principle of human thinking and thought (e.g., Forbus, 2001; Hesse, 1966; Hofstadter, 2001). According to these views transfer has to be placed *within* the framework of analogy, rather than the other way around. Although research into analogy frequently penetrates traditional cognitive boundaries, for instance by involving emotionality and social cognition (see Thagard et al., 2002), it is usually associated with *analogical reasoning* and *problem solving;* both of which are closely related to the issue of transfer (Robertson, 2001).

Keane and Costello (2001) view analogy as a process of structure mapping or structural alignment that has to be located within the interest areas of metaphorical thinking, similarity recognition and conceptual combination. Hence, discussions about analogy are all closely interwoven with those about *similarity, metaphor,* and *mapping*.

Metaphor refers to the use of a word or phrase to denote an object or concept not in a literary sense, but rather by suggesting an enhancement or replacement of the understanding and interpretation of the targeted object with the metaphor. The object we are indicating by a metaphor is *holistically mapped* onto the metaphor – and essentials of the metaphor's content are therefore transferred to the representation of the denoted object. Indeed, the term metaphor comes from the Greek word "μεταφερειν", meaning "to transfer" (see Ortony, 1991, for a good overview).

In contrast to metaphor, the concepts of *similarity* and *analogy* are less inherently linked to the mental nature of transfer because they refer only to the circumstance of the relation between two representations. Here, object P is "seen" to be *like* Q (according to the Latin word "similis", meaning "like") in certain aspects; and by inferring that there might be other similar states between P and Q to be found, P can be used as an *analog* for Q. Transfer by analogy is not understood in the holistic way as is the case with metaphorical substitution of meaning, but rather in a channelled fashion due to aspectual (perceived or inferred) resemblance between P and Q.

Unfortunately, there has been considerable uncertainty and disagreement concerning the conceptualization of similarity, ranging from holistic to dimensional and feature-based accounts (e.g., Vosniadou & Otony, 1989). And as some of these conflicts persist to date, they also led to the recognition of potential hierarchical structures of metaphors and analogies: "wholes" on one level are "aspects" on a higher level (i.e., as parts of a more inclusive "whole"). Thus, analogs can at the same time be constructed on *dimensional similarity* - and even entail metaphors - and still be *similar as a whole*. An analogy can, however, not be a metaphor on the same level of analysis, according to the explanations given so far. The main remaining subjects of debate for our purpose are (a) the decision about the dimensions, or elements, that are relevant for establishing an analogy, (b) the question about how to conceptualize wholes, and (c) the beliefs about the mental processes involved in the formation of an analogical relation.

Computational models of analogy and analogical reasoning

In recent decades, cognitive scientists have developed numerous computational models of analogy such as the Structure Mapping Engine (SME) and the "model of similarity-based retrieval" (MAC/FAC; Forbus, Ferguson, & Gentner, 1994; Gentner & Forbus, 1991), Analogical Coherence Models (Holyoak & Thagard, 1989, 1995) Learning and Inference with Schemas and Analogies (LISA; Holyoak & Hummel, 2001) to name just a few (see Gentner, Holyoak & Kokinov, 2001, for an overview).

Falkenhainer's (1987, 1990) Phineas system, for instance, employs analogical transfer by circling through the stages of describing, mapping, simulating, and analysing its input on the grounds of previously stored theories and examples. The crucial part in this cycle is realized through structural mapping (powered by SME) between a physical process and situation under observation and potential analogs. Structural correspondence can be described

as occurring under circumstances of recognized object similarity, similarity of the roles of the objects, and similarity embedded in object relations (Kokinov & Petrov, 2001). On the whole, the system compares and matches specific attributes as well as lower and higher order relational predicates. The need for exact correspondence as proposed by Thorndike's "identical elements" theory is relaxed through a principle called *minimal ascension* (Falkenhainer, 1988).

As memory research also suggests that retained information is far from static, i.e., it is flexible, interpretative, generically altered, and its recall and transfer are largely context-dependent (Kokinov & Petrov, 2001), further enhancements of the models became necessary. Associative Memory-Based Reasoning (AMBR: Kokinow, 1988; Kokinov & Petrov, 2001) is a model that can implement two sides of reasoning, i.e., *memory priming* and *contextual perception*. It treats transfer as a kind of interaction phenomena between memory retrieval and mapping, whereas transfer becomes very likely if the cognitive system has been primed with relevant experience just prior to a task, or if the task situation contains highly valuable contextual cues which trigger respective memory recall. Thus, recall influences mapping and mapping influences recall. The system then maps a source to a target piece by piece trying to build a constraint satisfaction network (CSN), similar to ACME (Analogical Mapping by Constraint Satisfaction; Holyoak & Thagard, 1989, 1995).

Within LISA's cognitive architecture, analogical mapping and retrieval functions are based on the premise that structural units in long-term memory (i.e., propositions, sub-propositions, objects and predicates) of source and target are represented by a collection of shared activated semantic units (Holyoak & Hummel, 2001; Hummel & Holyoak, 1997). However, capacity limits of the working memory limit mapping process to about three propositions that can be evaluated simultaneously as potential analogs. Bindings in earlier stages of a mapping process become therefore crucial to later ones, since they serve as a kind limitations to the "analogical reasoning space", which would explain how a transfer process can hamper itself, especially when initially only very few or domain-limited propositional matches are being considered ("suboptimal"), or when the learner takes an inappropriate first mapping approach to the novel task ("dead-end").

The inference step

Optimal grouping of information flow from the target, in order to be sequentially processed in the working memory is therefore crucial for successful mapping to a source. The best results of model fit have been demonstrated for the case where chains of propositions are presented in causal order (e.g., Keane, 1997). This causality structure probably aids especially the needs to make analogical inferences as part of the continuous mapping process. These inferences are believed to create a more abstract, generalized and elaborate understanding of tasks or situations which are mapped to each other, resulting in a higher order schema that covers both analogs; a process that is

also referred to as *learning step* in analogical reasoning (Holyoak & Thagard, 1997).

The concepts of schema induction and generalizable knowledge in transfer do not have their origins with computational cognitive models and have been used mostly outside of this research paradigm. They are is much better rooted with Gestalt research on problem-solving and "insightful" transfer that developed in the wake of the work presented by Judd (1908), Köhler (1917), Katona (1940), Koffka (1925), Duncker (1935), and Wertheimer (1945/59). It was these researchers that first introduced such important concepts as knowledge *structures, schemata*, solution *principles* and *abstract rules,* as well as *functionality* to transfer.

Selz (1913, 1922) and Wertheimer (1945/59) both emphasized the teleological character of thinking and its continuous aim to attain meaningful and holistic mental structures. Mental effort becomes crucial when a critical element to instantiate a solution is not featured in a subsequent problem set, and the individual is forced to search for a functional substitute for the left open "gap" in the solution schema. Transfer of functions in problem-solving, and especially the downside of this phenomenon, has also been investigated by Duncker (1935) under the header of *functional fixedness.*

Modern holism- and schema-guided analysis of analogical transfer is clearly an heir of the thought psychology introduced by the Berlin and the Würzburg schools (Gott et al., 1993; Novick, 1990; Novick & Hmelo, 1994). It was additionally inspired by the revival of the schema idea in the seventies and eighties across the fields of cognitive science (e.g., Lakoff, 1987; Minsky, 1975; Schank & Abelson, 1977). Today the main emphases with regard to transfer have become, on analogical reasoning, (a) based on concrete exemplars (Ross, 1984, 1987, 1989), (b) mediated by abstracted schemata or rules of isomorphic problems (Gick & Holyoak, 1980, 1983; Holland et al., 1986; Holyoak, 1984a, 1984b, 1985; Holyoak & Thagard, 1997), or, as mentioned above, (c) by employing structural mapping concepts (Bowdle & Gentner, 2005; Clement & Gentner, 1991; Gentner & Gentner, 1983; Gentner & Toupin, 1986). An alternative terminology for exemplar-based versus rule-based transfer can frequently be found in the form of analogical versus analytical transfer (e.g., Wattenmaker et al., 1995).

A slightly different emerging tradition has been the one involving mental models, which provide an alternative basis for the study of transfer by referring to adaptive expertise, i.e. knowledge and skills that are generalizable and adaptively applicable across contexts and domains of complex problem-solving tasks (Gentner & Stevens, 1983; Gott, 1989; Kieras & Bovair, 1984). Obviously, these knowledge types bear also a clear reference to the meta-cognitive and self-regulative themes in transfer, which I covered already in earlier sections (Brown, 1978; Brown & Campione, 1981; Campione & Brown, 1987; Mayer & Wittrock, 1996; Schraw & Brooks, 1998; Zimmerman, 1995).

Production system-based cognitive architectures

Anderson (1995) criticized preceding research on analogical transfer for its dominant focus on traits of the source and target in terms of *declarative* knowledge, instead of performance orientated processing aspects. This assessment echoed the fact that research on human learning and problem-solving started to put increasing emphasis on issues like cognitive skills and mental operators, which found implementations in a variety of cognitive architectures such as Soar (i.e., State, Operator, And Result; Laird, Newell & Rosenbloom, 1987; Laird, Rosenbloom & Newell, 1984; Newell, 1990; Rieman et al., 1994), CE+ (Polson, Lewis, Rieman, & Wharton, 1992; Wharton, Rieman, Lewis & Polson, 1994), and the development of several versions of Anderson's *ACT* theory (Adaptive Control of Thought; see Anderson, 1982, 1983, 1993, 1996; Anderson & Lebiere, 1998).

Anderson (1995, p. 348) points out for skill acquisition that declarative memory plays only initially a significant role and is in the course of practice quickly replaced by procedural memory; encoded and strengthened in the form *use specific production rules* (also called the effect of Einstellung; Luchins, 1942). The performance benefits from already compiled production rules are believed to be automatic, errorless, independent of each other, and largely independent of contextual variations of tasks within the same knowledge domain. Hence, the transfer distance between the performances in two tasks, or the solutions to two problems, is assumed to decrease proportionally to the number of share specific procedures. This procedural "proportionality-relationship" (Allport, 1937) is in effect the most straightforward interpretation of the Greek term of analogy, meaning *proportion*, and has in ideal cases of procedure-to-procedure transfer settings, been shown to make relatively good predictions (see also Moran, 1983; Polson & Kieras, 1985; Singley & Anderson, 1985, 1989).

Even so, the shift toward procedural knowledge forms did not only solve challenges related to the study of analogical transfer; it actually created a series of its own problems. Some of these are precisely related to the distinction and somewhat inconclusive characterization of declarative and procedural knowledge. Others stem from the assumptions concerning specificity and independence of procedures. Further, it was unsatisfactory that procedural transfer remained largely influenced by the extent of correspondence between superficial traits, as well as by the underlying structures and goals between source and target.

Instances versus rules

One potential theoretical controversy inbuilt into procedural view on skill acquisition and transfer is resonated in the concerns of *memory-assisted instance theories* that see transfer as being largely due to an increase in the capability to retrieve match specific examples (Logan, 1988, 1990). This line of theory emphasizes the point that learning and subsequent transfer is mainly a function of diversification and encoding specificities of the stimulus materials (i.e., the

examples); a view that is in clear contrast to the one of transfer as an effect of augmented fidelity and efficiency of procedural knowledge

Singley and Anderson (1989) recognized that declarative similarity between tasks may form a sort of transfer base on which subsequent procedural transfer can build (p. 197). This combined relevance of declarative and procedural knowledge during transfer was demonstrated in an experiment in the calculus domain (see also Brooks & Dansereau, 1987; Dixon & Gabrys, 1991; Harvey & Anderson, 1996; Royer, 1986), and signified a necessary step to account for models of transfer gains based on declarative knowledge (e.g., Just & Carpenter, 1987, 1992; Thibadeau, Just, & Carpenter, 1982). Also, Anderson and Fincham (1994) acknowledge that in the process of enhancement of procedural memory (i.e., rule training) subjects tend to memorize specific examples attached to them, which can be of significance during transfer (Anderson, 1987; Anderson, Fincham & Douglass, 1997).

The basic assumption concerning transfer within the ACT framework moved therefore closer to one that consists of an analogy-based mapping process between training source and transfer target within a 2x2-matrix of declarative and procedural knowledge. And in doing so, the models of the ACT family - by being candidates for a "unified theory of cognition" (Newell, 1990) – actually enhanced the strictly procedural transfer perspective of the cognitive complexity theory (Kieras & Polson, 1982, 1985). This was mainly achieved by combining modelling approaches based on the idea about production rules and symbolic representations of memory (i.e., the information processing approach), as well as semantic networks underpinned with neural networks at a sub-symbolic level of cognitive store (i.e., the connectionist approach). Thus, transfer can ultimately start out (a) from a state of absence of procedural knowledge (i.e., building on declarative knowledge alone), (b) from a knowledge state where only general, domain-unspecific production rules are known, and (c) from a state where specific production rules to partial problems are readily available.

Diluting the specificity assumptions about knowledge

In order to allow for these different modes of transfer, Singley and Anderson (1989, p. 248ff.) understandably also refrained somewhat from committing themselves too strongly to any particular assumptions about knowledge representation, especially to the ones concerning the exclusive role and inter-independence of production rules, and regarding their use specificity during transfer. Similarly, the ACT architecture takes a rather ambivalent stand on the question about the degree of granulation of the production rules, which is highly relevant for the question whether procedures are to be conceptualized as very abstract and domain-unspecific, or as very concrete use-specific skills (Müller, 1999; Pennington, Nicolich, & Rahm, 1995).

Use specificity of procedural knowledge, originally put forward as one of its key properties, considers a trained and informational encapsulated skill retrievable and applicable only when a task's conditions and goal structure

match those of the task where the procedure was initially compiled (Anderson, 1987, 1993; Müller, 1999). However, a strong use-specificity assumption often proved to be too restrictive. Müller (1999, p. 192), for instance, argues that even the declarative bridging between problems through the compilation of new production rules from a common conceptual knowledge base is too "slow and error-prone" (see also Harvey & Anderson, 1996). He challenges therefore the use specificity of production rules with an alternative hypothesis, named "conceptual integration". Pennington et al. (1995, p. 217) concluded from their experimentation that "declarative knowledge is the important source of … transfer", that it "is not use specific", and that the more elaborated the declarative knowledge base is in terms of conceptual understanding the better it transfers.

Müller (1999) further points out that within the ACT framework the amount of predicted transfer decreases with increasing practice. In contrast, the conceptual integration hypothesis implies that additional practice allows for the creation of more complete and integrated knowledge units, which can be accessed more easily for responding to source task as well as to target task. Although Müller's critique in this respect remains somewhat inconclusive, it is obviously in line with the arguments in Pennington et al.'s (1995) article, and provides a theoretical interpretation of the phenomena of conceptual transfer, rather than a mere quantitative evaluation and disapproval of the use specificity hypothesis.

Critically judged, it seems that both theoretical approaches struggle in identifying fully satisfactory forms of knowledge representations that can be used to denote the units and mechanisms of transfer. The questions about what kind of similarity really triggers and explains transfer, therefore, remain. Chen (2002), for instance, demonstrated that context similarities and *specific* procedural similarities alone facilitate transfer better than analogies with respect to mere underlying strategies and principles, even if such matches *are* recognized and mapped by the learner. These findings are in line with conclusions about the limited impact of abstract schemata or solution principles without the base of concrete examples (e.g. Bransford, Sherwood, Vye & Rieser, 1986; Gick & Holyoak, 1983; Reeves & Weisberg, 1994) and they also relate to the famous debate concerning the situated transfer thesis (e.g., Anderson, Reder, & Simon, 1996, 1997; Cobb & Bowers, 1999; Greeno, 1997; Greeno, Smith, & Moore, 1993; Lave & Wenger, 1991; Medin & Ross, 1989).

There also appear to be differences in the abilities to relate situations on a deep level that depend on one's learning history. Chi, Glaser, and Rees (1982) showed that experts tend to classify the physics problems more according to underlying principles such as Newton's laws, whereas the novices' classification is based on surface similarity, e.g., categories like "inclined plane problems," and "rotation problems." Therefore, only in cases where a newly encountered problem is superficially similar to one that they had previously solved successfully, novices are likely to try to use the same method to solve the novel challenge.

Remaining questions about type and abstraction level of similarity

Considering the diversity of transfer conditions, application domains, and contextual dependency of analogical thought, it is not surprising that few psychologists have conclusively put their fingers on what see as the essence of analogical relations. While the talk of "*sameness*" and "*transpositional similarity*" appeals to common sense, much about what *similarity* means precisely , how it is established mentally, and, therefore, what justifies analogical reasoning, remains unclear.

Overall, similarity constraint factors have been identified with respect to predicates, objects and propositions, relational and structural isomorphism, procedural matches, in relation to purpose or goals of tasks or episodes under analogical consideration (see e.g., Robertson, 2001), as well as in relation to the level or type of mental engagement (see results from research on Transfer-appropriate processing (TAP); e.g., Cermak & Craik, 1979; Francis, Jameson, Augustini, & Chavez, 2000; Jacoby, 1983; Roediger & Blaxton, 1987; Schacter, Cooper, Delaney, Peterson & Tharan, 1991; Vriezen, Moscovitch, & Bellos, 1995). As noted, analogical transfer and analogical memory recall has been demonstrated with respect to similarity in superficial traits rather than in respect to relational analogy or structural correspondence (e.g., Kaiser, Jonides, & Alexander, 1986), and has been best attained in within-domain and near transfer settings; in spite of the claim that similarity between analogs fundamentally refers to the qualitative "alikeness" in the relations that hold within one common structure of mental objects, and not simply to the quantitative surface similarity of properties or features from which analogy is then inferred (Forbus, 2001; Gentner, 1982, 1983).

In order to deal with the hierarchical nature of similarity constraints, Forbus (2001) also suggests the splitting-up and reintegration of a complex experience. This allows the matching of its parts separately to different partial analogs and can aid in relaxing the need to find a single complex analog, which alone often doesn't satisfy the quest for similarity, coherence and consistency of the transfer content. It remains, however, questionable whether human thought functions on the same analytical premise as computational models do.

Breaking organizational wholes into parts and merging parts into wholes has also been shown to act more as a constraint factor in transfer than as a facilitator. In addition to this reorganization predicament, Sternberg and Frensch (1993) have argued for three further mechanisms that enable, and therefore restrain transfer. These are encoding specificity, discrimination, and mental set, which are all based on learning and memory paradigms of cued recall and recognition, but merge also easily with the situational and use encapsulation as well as with the proceduralization arguments mentioned earlier.

There are also other cognitive transfer paradigms that have adopted this process-oriented approach of applying theories of learning and memory retention and retrieval to the study of transfer. TAP is certainly the most prominent one, targeted at exploring the transfer-enhancing factors in the

relation between the way knowledge is acquired and subsequently used (Morris, Bransford & Franks, 1977). It is closely connected to studies on encoding specificities (Encoding Specifity Principle (ESP); Thomson & Tulving, 1970), priming (Franks, Bilbrey, Lien & McNamara, 2000), context effects (Godden & Baddley, 1975), and state dependency (Bower, 1981; Eich, Weingartner, Stillman & Gillin, 1975; Goodwin, Powell, Bremer, Hoine & Stern, 1969) in learning.

2.3.4 Discussion of the contribution of different psychological approaches to transfer

The move towards mentality

The cognitive shift in psychology encouraged the research of mental forms and processes engaged in learning and transfer rather than the simple modification of overt *re*productional behaviour; a change in viewpoint that the early Gestalt psychologists and constructivists such as Köhler, Wertheimer, or Piaget had already propagated for a couple of decades. The investigation of cognitive dimensions in transfer became quickly the major driver of research across applied domains and cognitive transfer emerged in many ways as the quintessential view of transfer in general (e.g., Bassok, 1990; Bovair, Kieras, & Polson, 1990; Brown, 1989; Catrambone, 1996; de Crook et al., 1998; Gentner & Gentner, 1983; Gick & Holyoak, 1980, 1983; Logan, 1988; Reed, 1993; Ross, 1987, 1989; Shea & Morgan, 1979; Singley & Anderson, 1985, 1989). The downside to this development was the already mentioned researchers' and practitioners' increasing abandonment of research targeted specifically at socio-emotional and motor dimensions of transfer.

Contemporary developments and conclusions about motor transfer show evidently a high level of consonance with the cognition-based research; an effect that is in line with the general cognitive reorientation in psychology but somewhat obscures the fact that learning and transfer research has been initially dominated by the study of behaviour in a pure physical sense (i.e., motor behaviour), and still lends much of its presumptions to it (see chapter on conceptual evaluation). The investigation on physically enactive transfer has therefore become increasingly substituted by the investigation of mental representation and conceptualization of the transferred physical movement (e.g. Ferrari, 1999). There are in contemporary research no actual specific contributions related to motor transfer that justify separate mentioning.

Emancipating the cognitivistic view

The prospects of socio-emotional transfer research are in comparison more difficult to evaluate, mainly because of the immaturity of the research, and much weaker theoretical accord regarding the themes of emotion and cognition. Emotions are undisputedly important aspects of human adaptation to prior experiences (Tooby & Cosmides, 1990). There are however few theories that

directly account for affective dimensions as intrinsic aspects of the relation between mental representations. One is the connotative valence idea inbuilt into the analogical coherence model of Thagard and Shelley (2001), the other the pragmatic constraint proposal inbuilt into Holyoak's (1985) analogical transfer model. And indeed, as goals are at the very core of all human conduct, affective dimensions in human representations, and their relation to each other, need to be recognized as paramount in transfer. This is due to the conative character of emotions and motivations linking them to human action and goal-attainment.

In addition to these theories I have tried to point out the value of existing theoretical framework for the integration of socio-emotional dimensions in transfer theory. These include the views on socio-emotional transfer in terms of self-efficacy beliefs, simple conditioned reactions, global emotio-motivational schemata such as learned helplessness, as well as stereotypes and prejudices.

Cognitive transfer

It was, however, cognition-oriented theories that reinforced a series of key research frameworks to the study of transfer, including production systems, analogical reasoning (Gentner & Gentner, 1983; Gick & Holyoak, 1980; Holland et al., 1986), mental models, heuristics and meta-cognition (Brown, 1978; Flavell, 1976; Gentner & Stevens, 1983; Gott, 1989; Kieras & Bovair, 1984). Figure 2 illustrates in a simplistic way the dominant underlying model of analogical transfer. It starts with learning and ends with learning. The crucial mechanisms are those recruiting past experience, i.e., retrieval and mapping, and their use in understanding and coping with a current situation, by means of inference, and by conceptual combination. The indicated circular processes, taking place between retrieval and mapping, as well as between mapping and inference or conceptual combination, reveal the fact that a simple one-dimensional run through these transfer mechanisms would not ensure optimal transfer, especially in far transfer problems and with high-road transfer. In fact it is of course already there that learning and transfer takes place, especially when adopting a meta-cognitive point of view. The label of transfer is actually not much more than a "summarizer", signifying that retrieval and mapping and processes have taken place and therefore influence learning in situation 'B', i.e. in the form of available knowledge, production rules, problem-solving methods, and concepts, among others.

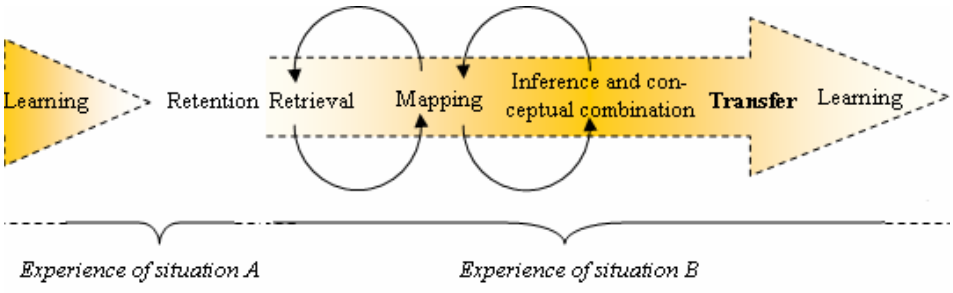

FIGURE 2 Simplistic model of transfer of learning

It is not surprising that self-regulative and meta-cognitive abilities, due to their essence as mindful reflections upon the development and relations between learning situations, have been awarded a very prominent role in transfer research across all domains (Butterfield & Nelson, 1991; Ferrari, 1999; Mayer & Wittrock, 1996; Ninness, Fuerst et al., 1991; Weinstein, Husman & Dierking, 2000; Zimmerman, 1995).

In spite of this, or maybe rather just because of this, the access flexibility to knowledge (e.g., Soini, 1999) and the predicament of the identicality constraint remained the main problem areas in cognitive transfer research. In spite of the manifold attempts to dissociate from one-to-one similarity concepts, the identicality constraint continued to produce most of the headaches to cognitive scientists. The bottom-line for any two "similar" objects or structures, no matter whether objectively defined or subjectively perceived as the same, is that *they are, in fact, at least partly different*. Therefore, if transfer by analogy is not to stumble over the boundaries of identical matches - be these superficial attributes between target and retrieved source, elements of declarative knowledge, procedural memory content, relational aspects, or otherwise - then the question what similarity means in the context of dissimilarity should be resolved. The focus should be on explicating the sameness in mental representations and assessing their impact on transfer; and not so much on the question "how similar is similar enough to be considered as an analog?"

3 RECONSTRUCTING COGNITIVE TRANSFER

So far, transfer research has been reviewed from a nomenclatural perspective based on discrete distinctions between transfer types (e.g., near-far, high-low), by outlining the status quo of transfer research in important applied fields, and finally, by use of a psychological domain approach exposing the relative significance and compatibility between motor, socio-emotional, and cognitive viewpoints on the phenomenon. It is now time to uncover the conceptual strings that tie these research fragments together, in the form of fundamental assumptions about the nature of transfer and its empirical manifestation. This means that it is the time to engage in the reconstructive endeavour.

The deconstruction deliberations in the first section will lay out the foundations of the reconstructive work that is continued in Section 3.3, aiming at the formulation of a new theoretical framework. Section 3.4 will then complement the conceptual and meta-theoretical considerations by presenting empirical substantiations for the new reconstructed theory of transfer.

3.1 Deconstructing the reviewed transfer research

As the classic method of synthesis usually follows analysis, reconstruction starts here with deconstruction. This means we need to loosen up and reveal essential constituents of current theoretical complexes in order to judge and decide the kind of novel framework needed to explain transfer and advance its research. However, deconstruction goes also further than analysis, because it does comfort itself by taking things apart and sorting them out. Deconstruction aims at revealing deeper seating quarrels and limitations in argumentation. Section 3.1.1 will first concentrate on revealing underlying consonances and dissonances between current theoretical approaches to transfer and link their concepts to broad paradigms. In Section 3.1.2 the same trenches between approaches are examined with regard to its empirical implications.

In general, I shall focus here forth on transfer research that is based on cognitive concepts. This is mainly because cognitive transfer research has recently been the most active, offering domain-pervading perspectives, and also because the reconstructive work and theoretical proposal of this thesis will be based on explanatory constituents in transfer that are cognitive in nature.

3.1.1 *Common element*-based and *schema*-based tradition in transfer research

Evolution of concepts

Much like in Darwin's "Origin of Species" theory, scientific concepts are subject to evolution processes. Concepts find their inception in reference to something, by implication of a set of attributes, and through use within the propositional or theoretical context of human thought (Saariluoma, 2002). These aspects may subsequently be interpreted in a variety of ways by different people in different circumstances. The attributes of scientific concepts, for instance, may also change over time, while accommodating to and assimilating with research results and theoretical frameworks. Generally however, whenever used, a concept is seen to serve a certain purpose within a network of functional relations of concepts, typically an explanation or a theory. There exists, further, a certain broader paradigm or methodological culture to which concepts are best adapted, i.e., fitting. They coexist next to other concepts within this environment that may compete with them for the same resources, i.e., raison d'être. And finally, concepts may have a limited life-span, although they may under certain circumstances be revived after a period of abandonment, e.g., as an effect of re-conceptualizing their attributes and use.

In studying transfer, the questions are therefore: (a) what are the species of concepts that have populated research so far; (b) what is the particular theoretical environment or tradition they are best fitted to; (c) how are they used; and (d) what is their relationship to other concepts within and across theoretical frameworks?

The cornerstones of cognition-oriented explanations of transfer are obvious. First, with the nearly unifying cognitive metaphor quickly becoming known as the information-processing approach (Eysenck, 2000; Kuhn, 1970; Lachman, Lachman & Butterfield, 1979), and with the understanding of the learning individual inspired by the General Problem Solver (GPS; Newell, Shaw & Simon, 1958 and 1960; Newell & Simon, 1963, 1972), cognitive research brought forth a variety of computational models and methods to study and simulate knowledge acquisition, retention, and use (e.g. Anderson, 1983, 1985, 1993; Anzai & Simon, 1979; Atwood & Polson, 1976; Hayes & Simon, 1974 and 1977; Simon & Hayes, 1976). This also provided the framework to Singley and Anderson's (1985, 1989) cognitive account of Thorndike's identical element theory, by putting emphasis on the classic knowledge form distinction between *declarative* and *procedural knowledge* (Anderson, 1995) as well as between *weak problem solving methods* (i.e., generalized, domain-independent knowledge and

skills) and *strong problem solving methods* (i.e., domain specific knowledge and skills) (Anderson, 1987, Klahr, 1985; Larkin, 1985; Newell, 1980; Newell & Simon, 1972; Simon & Simon, 1978).

The other cornerstone was laid by Gestalt psychologists already in the first half of the 20th century. They continued Judd's (1908) line of work resulting in further accentuation of "insightful" transfer, using terms like knowledge structures and schemata, solution principles, and functionality (Katona, 1940; Wertheimer, 1945/1959). Both research approaches have also received considerable input from such application fields as educational psychology, human-computer interaction, verbal learning and inter-language transfer.

Paradigm-driven families of transfer theories

Hence, cognitive notions have in general developed driven by the dominant psychological paradigms such as Associationism and Connectionism, Behaviorism, Gestaltism, and Cognitivism; and their use and rationalization must be seen against this background. GOMS and ACT-based procedural transfer theses are a good example of modern explanations fitting the atomistic and mechanistic nature of the Connectionist paradigm, i.e., by seeing transfer as an effect of commonality in semantic conditions-action-goal structures, mainly instantiated as IF-THEN production rule associations overlap. This view on transfer clearly replaced Behaviorist explanatory concepts of stimuli and response with more sophisticated mental concepts that serve as units of transfer. The cognitive architecture background also added important processing capabilities and some degree of flexibility concerning the identicality constraint (e.g., declarative-to-procedural, and declarative-to-declarative transfer); it did however not essentially defy the common underlying *common element-based* thought model of transfer.

Both the original habitual response-based idea of common element transfer as well as the modern production rule compilation and knowledge encapsulation account are in their core assumptions already refuted by Gestaltists' theories. Koffka's (1925) scrutiny of Thorndike's (1911, 1913) and Köhler's (1917) arguments and findings revealed that explanations of learning and transfer based on the notions of association and automation fall short of explicating the nature of mental activity even for simple problem solving tasks. Novel explanatory concepts were needed to account for "learning by understanding" (Katona, 1940) and problem solving transfer (Mayer & Wittrock, 1996). These were found with reference to the organization and structure of knowledge (Clement & Gentner, 1991; Gentner & Gentner, 1983; Gentner & Toupin, 1986), abstraction and general principle inferences (Bourne, Ekstrand, & Dominowski, 1971, p. 104ff.; Judd, 1908, 1939; Simon & Hayes, 1976), the goal- and meaning-directedness of thinking and its holistic nature (Bühler, 1907, 1908a; Holyoak, 1985; Humphrey, 1924; Selz, 1913, 1922), and functional relations (Duncker, 1935; Köhler, 1917).

Because this tradition of investigating transfer is based on Gestaltist ideas, we could summarize them under the header of *schema-based* theories of transfer.

In general, however, they emphasize various aspects of the quality of mental representations (Gott et al., 1993; Novick, 1990; Novick & Hmelo, 1994). And as a consequence of this change in perspective on learning and the nature of the employed concepts, new notions with relation to transfer needed to be introduced. These were found with such concepts as functional fixedness, "Umzentrierung", transformation and resonance (Duncker, 1935; Wertheimer, 1945/59), mapping, coherence, and, isomorphism (Gentner & Toupin, 1986; Gick & Holyoak, 1980; Reed, 1993; Reeves & Weisberg, 1994; Thorndyke & Hayes-Roth, 1979).

Differences and complementarities

Hence, we not only see the rooting of transfer research in different paradigms, we can also see how these differences have emerged in rather separate traditions of looking at transfer. The discrepancies can not be explained on the grounds of disagreements about the basic definition of transfer, referring to the core elements, i.e., learning and similarity. The dispute is anchored in the disparate understanding of these fundamental concepts. However, the differences in underlying viewpoints on cognitive explanation of learning and transfer have at times been so profound that it has been argued that the members of the two families of theories are not applicable to the same understanding and conditions of learning and transfer. This means they are not conflicting but complementary views.

This view has also been resonated in the frequent generation and underlying rationale of transfer taxonomies, as well as in the practice of associating either theoretical approach with some type of learning and transfer only: rote memorization vs. meaningful learning, effortless (automated) vs. effortful (insightful) performance, skill transfer vs. problem solving transfer; within domain vs. across domain application etc. Naturally, this does not necessarily provide a conceptual foundation that is favourable for developing a unified understanding of transfer. And in this sense, complementary views on one and the same phenomenon convey a prophecy of conflict.

It is also necessary to note that it would be opportunistic to assume that the categorization of transfer views into common element- and schema-based approaches is necessarily exhaustive. These two models and their underlying paradigms are simply recognized as the most evident and influential prototypes. However, a more pluralistic or finer graded categorization would not lessen the reconstructive argument, it would only accentuate it.

3.1.2 Empirical implications

Methodological considerations

Naturally, the evolution and impact of scientific concepts is not solely dependent on acts of contemplation and debate within the research community, but rather on the effect of probing their value in constructing, operationalizing,

and testing theoretical hypotheses. As a consequence of this, we should find the conceptual differences outlined above also reflected in empirical work. The key issue from an evaluative stance is not so much to compare the amount of empirical support put forward for either approach to transfer. Much more essential is to uncover tacit assumptions that are inbuilt into the respective empirical paradigms, and to relate them to the conceptual differences.

As with all research progress that employs deductive principles, the process of constructing hypothesis and designing experiments is closely tied to the upheld theoretical explication of a studied psychological phenomenon. This means that in general only what is believed to be worth measuring is operationalized, observed, and recorded. And subsequent exploitation of the collected data to understand the phenomenon under investigation relies on these theoretical underpinnings. In consequence, emerging knowledge is fundamentally bound to the explicit and implicit theoretical limits (e.g., presuppositions) that are set in advance (see also Saariluoma, 1997). All this is also relevant to the case for transfer research.

My general view on experimentally induced transfer is that it is highly concept and method dependent, and explanations of the data reflect first of all the researcher's view on the learning situations and their relations. This is the representational predicament of transfer research that is addressed rarely (Issing, Hannemann, & Haack, 1989; Novick, 1990). Further, experimentation-based assessment of transfer usually neglects more or less consciously the influence of all prior experience that precedes the experimental window of observation. Schulz (1960), for instance, argues that problems are often only problems because we transfer experiences from inappropriate sources. This may include inferred unnecessary constraints and inappropriate "world knowledge" (Robertson, 2001).

The logic of transfer experiments

Before looking at more concrete examples, I sketch out the general logic of transfer experiments. Its main ingredients are two diachronically separated situations, i.e., the primary and secondary learning situation, "a mind" that is experiencing both of these, and a measurement that captures the person's behaviour. Implications about transfer taking place are dependent on the distinctiveness of the collected data from conditions where the primary learning situation has been missing or is different in nature. Usually, the latter is preferable, because it allows for a better control of learning effects, inherent to the primary learning-secondary learning sequence. Hence, transfer effects in the experimental group are usually conceived of as total (gain in) performance minus learning curve-estimate, derived from the control group. It is difficult to speculate about the type of relation inherent to the two learning situations in the control condition that would allow filtering out transfer effects only, i.e., without being contaminated by transfer effects itself. This is a technical reformulation of the argument countering the separation of learning and transfer.

Applying this experimental paradigm in an inductive manner, we would now need to investigate whether the obtained performance gain is specific to the chosen pair of learning situations, or whether there are other primary learning situations that render similar transfer results. Finally, we would have to compare the pairs that produce similar results among each other and contrast them against those that produced discrepant results, including those of the control conditions. In doing so we would try to reach a conclusion about the relevant instances of commonalities and differences between them.

Naturally, this is hardly ever done, and in the absence of any a priori assumptions about the relevant dimensions of similarity in terms of stimuli, context, mental representation, mental processes, etc. it is also hardly feasible to engage in such an endeavour. It is simply inconceivable to construct and compare multiple pairs of learning situations without the implicit guidance of some preconception about psychologically relevant dimensions. With regard to cognitive psychology this means cognitive functioning in general, and learning and similarity in particular. Considering the theoretical views taken on transfer, it is also self-evident that the conception of the distinct relevance of different primary learning analogs is by nature more associated to the schema-based theories, because of their emphasis on effortful retrieval processes, mapping, and schema induction. (Gick & Holyoak, 1983; Holyoak, 1984a).

In summary, we would expect that the bulk of transfer experiments are inherently tied to researchers' preconceptions, both on the side of the devised learning situations that are investigated as well as on the side of the collected data and their interpretation. And this is indeed what we find. Already Thorndike and Woodworth (1901a, b, c) speculated, for instance, about the actual units of transfer being of mental, i.e., perceptual nature. They did, however, not pursue this idea because it did not suit the dominant psychological paradigm at the time.

Empirical presumptions

The number of empirical presumptions inbuilt in transfer experiments is rather large. First, in order to emancipate transfer research from delimitations to Behaviourist' stimuli and response elements, or purely situated arguments of context, decisions need to be made about the mental constituents or processes that are of interest. Is it some factual knowledge, automated skill, strategy awareness, or some general mental proficiency? These are the units of transfer that researchers presume to be similar or related to each other in some relevant sense. Secondly, the researcher has assumptions about the nature of similarity or relation these units imply and about the way they are psychologically established. Are they identical matches, hierarchically nested, or coherence-based perhaps? Is similarity realized through a mechanistic check for correspondence, through a structural mapping process in mental representation, or is it an issue related to highly effortful inferential operations?

Task presumptions

Those interested in transfer within learning hierarchies will design learning tasks accordingly, and thus imply many other types of relations between tasks that have also been shown to be beneficial, such as the presentation of learning sequences with slight increase in difficulties (Gagné, 1968; Hull, 1920; Sweller, 1980). Those subscribing to the production system view on cognition commonly favour an operationalization approach that has participants learn artificial production rules in terms of mathematical calculation rules or functions defined within some programming language (e.g., LISP). Procedures should be simple in application and learning and lean with regard to declarative knowledge (i.e., as meaningless as possible) (Anderson & Fincham, 1994; Anderson et al., 1997; Kessler, 1988; McKendree & Anderson, 1987; Müller, 1999; Pennington & Nicholich, 1991; Pennington et al., 1995). Some self-confining effects of this experimental practice are evident from Anderson and Fincham's (1994) experiments on the asymmetry of procedural transfer. The authors found no significant gain in performance from training calculations such as +1, to the reverse operation of -1. It is however, difficult to see how a +1 should in anyway more inherently be associated with -1 than with +2, except for the reference to some explicit awareness about this reverser rule in a declarative sense. In fact, this declarative elaboration is usually discouraged by employing vigorous repetitive strengthening of productions rules. Symmetry in procedural transfer can be better shown with the evaluation-generation paradigm using LISP functions, because it allows for the acquirement of richer (more meaningful) declarative knowledge about procedures (Pennington & Nicholich, 1991; Pennington et al., 1995).

Schema-based experimental research of transfer mostly relies on success rates in solving isomorphic variants of some famous source problems such as Duncker's (1935) radiation problem, the "Tower of Hanoi", or the "Missionaries and Cannibals" problem (Gick & Holyoak, 1980, 1983; Greeno, 1974; Reed, Ernst, & Banerji, 1974; Simon & Hayes, 1976; Thomas, 1974). Common conclusions refer to the superficial constriction of this kind of transfer. This may, however, be exactly the effect of the often extraordinary contents of the problems and highly artificial nature of the relation between them, resulting in a highlighting of surface traits and semantic differences (see e.g. Reed, 1993; Ross, 1987; see also Liu & Vaina's, 1995, argumentation concerning stimulus-specific transfer as a consequence of stimulus-specific experiments). Experimental subjects may also be sensitive to design and purpose, thus assuming that the presented tasks must be in some way be related, and searching for links "at a wrong place" (Keane, 1987). Better results have here been obtained when the isomorphic relation is superimposed to a progressive increase in problem complexity, which may serve as an additional hint at learning relation (see Reed, 1993).

Domain presumption

It is obvious that the problems with domain-pervading far transfer has been frequently a stumbling block in schema-based transfer research, mainly because this type of transfer initially best suited the investigation of its claims and has therefore also been employed very frequently. As a consequence, the assumptions of domain-specificity of representations have often been incorporated in analogy theories and empirics, allowing researchers thus evade the need to challenge their basic concepts.

Procedural transfer experiments are on the other hand specifically designed upon the premise of common elements in near transfer settings. The reason why domain-constraints have not been equally intruding can be recognized with Singley and Anderson's (1989) original objective for modelling transfer in order to investigate the creation and transfer use of *domain-specific* (i.e., target-task focused) procedural knowledge.

Finally, there may also be domain-restrictions to transfer that stems from participants' beliefs about the common function of the knowledge and skills attained in the different domains, rather than caused by the designated domain borders themselves. An example for this is the asymmetric transfer between mathematical principles acquired in the supporting domain of algebra and the applied domain of physics (Sternberg & Frensch, 1993).

Hence, theoretical underpinnings will to a large extent define the chosen stimuli, the situational context of the experiments, and the type and quality of the mental operations required. This includes the kind and degree of mental effort and mindful involvement, the subjective meaningfulness of the task and involved knowledge, and eventually may decisively influence the way knowledge is acquired and how it transfers (Rabinowitz & Goldberg, 1995).

Observational presumptions

Assumptions about the nature of learning and transfer are decisive for the kind of effect and control measures an experimenter chooses. Research on procedural transfer commonly relies on performance indicators such as speed and accuracy. This leaves the research rather blind for variations in transfer that may be instantiated in different sub-goals and solution-paths of task solving (see e.g., Rehder, 2001; Woltz, Gardner and Bell, 2000); a fact that has frequently encouraged the call for intensified investigation of actual knowledge that is acquired and used during transfer, including the way it is applied (Anderson & Fincham, 1994; Butterfield & Nelson, 1991; Pennington et al., 1995; Reed, Dempster, & Ettinger, 1985; Wattenmaker et al., 1995). For schema-based transfer, Reed et al. (1985) demonstrated, for instance, that 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 or errors along the way leading to successful transfer (see also Novick & Holyoak, 1991).

Theory-based inferences about transfer that are based solely on observations of performance in the transfer situation generally presuppose that

what is believed to transfer was not only learnable but has indeed been learned in the primary situation (Brown, 1989; see also Barnett & Ceci, 2002, p. 616). As stated by Reed et al. (1985), meaningful transfer necessitates that the presented problems are understood on a meaningful level. This is an issue that has been awarded much attention especially in inference-based and meta-cognitive type of transfer research (Gott et al., 1993). It often led to specific instructions of participants to actively reflect and elaborate the learned knowledge, or the direct presentation of the extracted rules and other hints (Bourne et al., 1971; DiVesta & Walls, 1967; Fong, Krantz, & Nisbett, 1986; Gick & Holyoak, 1980, 1983; Goldbeck, Bernstein, Hillix, & Marx, 1957; Lockhart, Lamon & Gick, 1988; Reed et al., 1974; Ross, 1989; Scandura, 1966). Obviously, such practices do not necessarily strengthen the significance of the obtained results, despite Brown's (1989) counterargument about the equally widespread tendency among experimenters to artificially disguise the relation between learning situations.

Failure of transfer predicament

Obviously, instability of transfer, especially far types, has haunted empirical research across theoretical borders (Bassok & Holyoak, 1989; 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; Novick, 1988, 1990; Reed, 1987; Reed et al., 1974; Simon & Reed, 1976; Ward & Gow, 1982). Often, the reasons for transfer failures may also simply relate to the question of whether the dimensions and elements that researchers thought to be salient are equally relevant to the participants. De Crook et al. (1998) have reported an experiment where their subjects studied a virtual simulation of alcohol-distillery plant, and trained system troubleshooting. Task cases were distinguished by types of failure (valve malfunction, leakage, controller malfunction and alarm failure), and subsequently interpreted as the transfer elements in experimental analysis. It is difficult to see how these elements could be relevant outside of the nomenclature of different experimental conditions, i.e., with regard to the actual experiences and tasks of subjects. The need to construct units that satisfy common element approach has also preoccupied other experiments (see e.g., Wattenmaker et al., 1995). Similarly, superficial constraints of transfer are more likely to emerge from such surface details that were experienced as relevant in primary learning, while other superficial and contextual details might easily be unavailable to enhance transfer (Gick & McGarry, 1992). Underwood, Ham, and Ekstrand (1962) introduced in this context the distinction between nominal stimulus and functional stimulus.

Limits of transfer or limits of its conceptualization?

In general, I will not refute that there *are* natural (i.e., mental) boundaries to when, where, and how transfer occurs. The key questions are whether the experimental paradigms themselves implement such barriers in an implicit

form and whether transfer actually has occurred but was not detected because of inappropriate theoretical concepts and/or empirical measures.

The common element paradigm tends to make very conservative predictions about the amount of transfer in trans-domain contexts, with failure of transfer being probably nearly the default expectation. It also encounters conceptual difficulties to account for negative transfer, i.e., the case where inappropriate procedures are triggered. This is mainly due to its inherent contradictive theoretical implication: The carrying over of elements which are not shared between the source and target transfer situation frankly do not belong into the picture of the common element-based conceptualization of the phenomenon. Common element-based research makes, however typically, strong predictions for transfer conditions with high stimuli and contextual overlap, which is exactly the premise most experiments are built upon.

Seemingly the same factors, i.e., superficiality, are the Achilles' heel in schema-based experiments. This is at first not surprising, considering the adaptive value in human phylo- and ontogenesis associated with the attention to stimuli information (Brown, 1989; Gentner, Rattermann, & Forbus, 1993; Medin & Ortony, 1989). However, "what we want to find out is precisely the psychological equality despite dissimilarity in a physical or other respect" (Bühler, 1908b, p. 107-108). This warrants us to question whether production system models or structural accounts of human representation provide us with the conceptual capacity.

3.2 Demarcating the phenomenon anew

In the following I shall continue the reconstructive work that started with the critical evaluation of transfer research in the previous section chapter. I will start to pick the fruits, if not to say the "grapes of wrath", of the ideas I planted so far. Based on the argument of theoretical inconsistencies and limited conceptual capabilities, a reconstructed view on transfer will be presented. In the way that the term reconstruction relates to the issues of goal-oriented modification, enhancement, reinterpretation, and reorganization of existing representations, in order to adapt them to new challenges and generate new meaning, this attempt is in itself a case of mindful problem-solving transfer. It means, that the reconstructed approach to the explanation of transfer presented here is naturally influenced by the experiences I had when considering previous accounts of transfer, as well as other relevant psychological questions.

In order to proceed I need to demarcate the phenomenon of transfer, and for this I shall present a 9-point conceptional framework. The arguments put forward are developed from the discussion of transfer in the review chapter. They include a declaration of how I conceive of transfer and where I see the core challenges for research and theory development.

1 *Cognition implies transfer*: Transfer is here conceived of in terms of a genuine constructivist concept. It is omnipresent and accompanies all psychological processing of world affairs. Humans never encounter a situation in a mental state of "tabula rasa". No representation of a target situation is therefore free of transfer, i.e., target problem situations do not receive a learner's attention in a transfer-free state of mind, upon which the actual process of transfer commences (e.g., mapping and retrieval). On-the-spot representation of any situation is already the product of some transfer having taken place. This view makes, thus, a strong emphasis on what is usually called implicit transfer.

2 *Transfer is neither a cognitive process of its own, nor really in itself*: Transfer is in its mental underpinnings not principally distinct from learning or the construction of mental representations in general. Rather it expresses a particular viewpoint of looking at these phenomena; namely the one explicating relations (i.e., dependency, inheritance) between constructed representations.

3 *Transfer is neither a one-shot nor an all-or-nothing phenomenon*: Transfer signifies the ongoing attempts of the individual mind to make sense of present situations by selecting, integrating and reorganizing mental contents on the basis of or influenced by previously constructed mental representations. In the course of transfer an individual passes through continuous transitions of resetting and reorganizing representational content.

4 *There is never only a single source for transfer*: Transfer commonly engages a series of mental contents and their inter-relations that have been relevant in different experiences in a learner's biography. This means that several sources for transfer are relevant both in sequence as well as simultaneously to each other, for attaining an appropriate understanding of a current situation.

5 *Positive and negative transfer effects are not mutually exclusive*: Actual transfer in terms of its experiential realization and behavioural effects must always be seen as the sum of mentally established relations that are appropriate, sub-optimal, or inappropriate for making sense and/or coping with a current situation.

6 *Transfer and similarity are interdependent concepts*: It is tautologous to define transfer as based on some kind of similarity between situations as such, because the similarity between situations is in fact the mentally evident consequence of transfer. Doing so, signifies generally the difference between the conception of similarity in the

eye of the researcher constructing experimental conditions for transfer, and similarity as apperceived by the transferring individual constructing mental representations of the encountered experimental situations.

7 *Principality of the study of the mental exertion of transfer:* The study of how transfer is mentally established must lead the concerns about the positive and negative effects associated with it.

8 *Transfer research is concept-driven and condition-dependent*: As with all research our concepts bias our view of the studied phenomenon and prejudice the type of conditions we investigate. While doing transfer research, we declare a chosen context for learning, within which the construction of a mental relation between a primary and a secondary learning event can be expected and predicted. The investigation of the actual mental processes that have taken place can therefore not be fully replaced though effect-based inferences.

9 *Theoretical concepts must contribute to the unification not segmentation of transfer research:* We must seek such theoretical concepts that can assimilate the diversity in the mental nature of transfer, rather than accommodating the theories to varying instances of the phenomenon. For this we must uncover relevant dimensions of transfer as constituents of mental representations and present theoretical concepts that can account for these.

The omnipresence of transfer in human cognition is an important argument, associating it with the process of constructing mental representation in general. In paraphrasing P. Saariluoma (personal communication, March 13, 2002) I assert that as humans we can not think anything else or more than what are the contents of our mind. And for that matter, we can in fact also not think anything less than that. Therefore, when entering a new "Lebensraum" (Lewin, 1963) or simply when encountering an unfamiliar stimulus, our immanent experience will be synthesized from currently generated mental contents that are the direct product of the present situation or of mental origin, i.e., through activating, enhancing, and restructuring information from prior constructed mental representations. As a result of this, a new mental reality is created which draws on earlier experience, i.e., transfer takes place.

For the case of learning it can be said that it is characterized as a process and product of an experience induced assimilation-accommodation interaction between the two content systems *person* and *environment,* resulting in a subjectively activated build-up and modification of mental contents and structures. And in so far as every construction of mental representations recruits contents that have already existed before, *all learning relies on transfer*. Through learning, humans refine understanding, improve performance, and,

get better at learning. The crucial momentum of transfer is to reduce novelty and complexity and to enhance meaning in a present learning task by employing prior experience.

A further problem that has been encountered in experimental contexts stems from the fact that we can actually not limit transferable and transferred learning experiences to the learning situation that we construct. This is so, because knowledge can be transferred from any previous situation in the learning biography of an individual, not just from the one set up for the sake of experimental observation. It is probable that a person has already previously learned what we want him or her to learn in our training situation, or other things that may be just as relevant to transfer.

We need therefore concepts that are not specifically based on the idea of a mental *comparison* of two situations, but rather focus on the process of constructing a current representation based on a variety of mental contents, and to identify those that serve as a carrier in transfer. Obviously, nobody possesses two minds, which would enable aligning one experience with another, so that knowledge could be "*carried over*". Rather, we have only one mind, and the best suggestion we can make is that current experience is not independent of mental contents and of the characteristics they incorporate related to their contribution to prior experience. Thought is also not just a partial reoccurrence of prior thought, but rather depends on specific selection, integration, and reorganization process of prior relevant contents.

3.3 Developing a mental content-based theory of transfer

3.3.1 Recapitulating the basic research questions

To recapitulate: Transfer research encompasses three basic questions:

1. Under what (situational) conditions does transfer occur? (*Conditional* view on transfer).
2. What are the transferred units? (*Medium*-oriented view on transfer)
3. How does transfer function? (*Process* definition of transfer).

It is clear that these questions are neither independent from each other, nor trenchant in their distinction. Still, answers to them must be found in the transfer theories (as explicit statements or implicit assumptions), and they must have a recognizable effect on conducted transfer experiments and their findings. In so far as the current perspective on transfer is that of an omnipresent, continuous incidence of experience, we are primarily concerned with Question 2 and 3, and make only later some empirically based implications concerning the Question 1.

3.3.2 Arguing for *outside*-paradigm reconstruction

Choosing a framework or developing a new one

As has been demonstrated thus far, the present situation of transfer research is not one of absence of theories or concepts, quite to the contrary. By adopting one of the views presented, it is therefore relatively straightforward to answer the three questions above. However, we would come to very different types of answers about transfer; a situation that does not fulfil our aspiration of a unified view. This fact can for instance be seen from the active debates concerning the relevant aspects and units of transfer between the proponents of different research communities (e.g., Gentner, 1983; Holyoak & Thagard, 1989, 1995; Singley & Anderson, 1989; Thorndike & Woodworth, 1901a).

Further, in making a choice about which theoretical tradition to adopt, i.e., the common element approach and the schema-based view, we realize that a simple refutation of either set of proposals is not possible on the basis of empirical findings alone. In fact, both bodies of research have provided much evidence for making valid predictions in well chosen transfer circumstances. However, the theories have been less successful in instigating and explaining transfer when typical conditional requirements are swapped between paradigms. This has been documented by a long list of findings about so called transfer failure, and has repeatedly encouraged discussions about the intricate interaction between surface and deep similarity (Goldstone, 1998, Goldstone & Sakamoto, 2003; Holyoak & Koh, 1987).

Within-paradigm versus outside-paradigm development

There are two basic ways out of the conundrum spelled out above. One is *within*-paradigm, the other *outside*. By pursuing the first option we could either try to reduce controversies between theoretical propositions by delimiting their scope and making them more specific or by stretching the frameworks to incorporate the assumptions of the other. Both of these options have been applied frequently. Whereas common element- based theories by nature imply clear applicative limits to the range of transfer conditions, schema-based theories of analogical reasoning have tried to account for identicality constraints and relational correspondences within the same coherence mapping framework (Thagard, 2000). Indeed, under some circumstances, the two transfer models have proven to be quite complementary in their explanations and predictions of transfer. An experiment that implicitly employed such a liaison between the approaches was conducted by Zamani and Richard (2000), but may be criticized for the apparent necessity to make rather rigorous assumptions about participants' analogy-relevant representations of solution path sub-goals as well as the loosening of the identicality definition with regard to the identification of stimuli elements. Thus, although the authors set out on a mission to combine predictions for low-level similarity effects with those stemming from the investigation of representational dimensions in transfer, it seems that this

synthesis obliged them to make a series of additional delimitating presumptions. Chen (2002), too, attempts to establish the case for a distinctive influence of procedural information beyond surface and structural similarities. Unfortunately, it is difficult to discern in an unambiguous way, what he infers by the concepts of procedure, strategy, principle, similarity, etc. Further, the experimental conditions in the procedure versus principle learning distinctions differed also greatly with respect to the elaboration of additional solution-relevant information that was provided; hence, the nature of primary learning was very distinct.

Overall, I defend therefore the opinion that theoretical reconstruction must continue *outside*-paradigm. The reasons why it is necessary to introduce novel concepts and conduct to transfer research are, nevertheless, not only based on the conclusion about theory-based controversies and related empirical quandaries. They also lie specifically with the explanatory *capacities* (compare also "power of expression" as used by Saariluoma, 1997) of the concepts themselves, as well as with other persisting shortcomings in traditional transfer research that have been laid out in earlier sections.

Transfer in the eye of the beholder

The first predicament in transfer research is that explanations remain generally based on a conceptual language that finds its origin and validity with the judgment of the researcher or the characteristics of the learning material and situation, instead of the mentality of the individual engaged in transfer. The cognitive reorientation has definitely recognized this problem as immanent to the early Behaviourist conception of transfer, but it has not really solved it. As has been argued throughout this thesis, this is true especially for typological distinctions between near and far, or similar and dissimilar, but holds also for domain classifications. It is the very essence of transfer that when successful, far becomes near, and the impression of similarity is established in the same course. It is also valid to question the causal direction of an effect relation between transfer and domain barriers, especially when the domain map is drawn up from the researcher's point of view. Transfer in many ways not only overcomes domain barriers, by doing so it actually removes or relocates them. Another critical concern is the stimuli-based decisions on what is meaningful or what requires effortful mental engagement. This, too, depends equally on the individual learner and indeed on the occasion, type, and progress of transfer itself.

Form and structure do not explicate the essence of thoughts

However, even such concepts that are generally used to denote the inherent cognitive nature of human experience and thinking are questionable as true candidates for rich mental concepts when put under scrutiny. This includes the differentiation between abstract and concrete thoughts, production rules, representational structures, schemata, deep transfer, and the like. There are

several practical and theoretical problems with these notions about thought and knowledge types.

Trivially one may argue from an inter-individual perspective that what may be considered as highly abstract to some may be very concrete to others because of the availability of a larger knowledge base including concrete instances of extracted structural information or general rules. It is also obvious that to some individuals, knowledge may be available in factual form, but they have not yet compiled production rules that tie declarative information together into skill units of procedural knowledge. Other individuals may in turn have transformed knowledge into an encapsulation mode, allowing for a very cognitive efficient use. Similar to the argumentation above, this would pose problems in explaining experimental results based on general assertion of what is abstract.

The matter is however more profound. It lies with the just used notions of *structure* and *form* and *efficiency* to account for human cognition. Although human thinking may be looked at from those perspectives they do not serve well to explicate its true psychological essence (Helfenstein & Saariluoma, 2005; Saariluoma, 2002, 2003). The human mind is neither recursive nor are the mental representations it instantiates manifold in their fundamental nature. Human thought is at its core neither about nor a phenomenon explainable by neural activity. This is not to say that cerebral correlates may not be measured and analysed to enhance or complement our picture of the mental processes taking place during transfer. It is, however, difficult to imagine how explanations of transfer could be grounded on this form of information, except maybe for the very obvious cases of failure or capacity issues related to lesions in different brain areas, as well as modality-related stipulations of perception- and motor-based processes in general. The study of human thinking can therefore neither be replaced nor reduced to the investigation of substance.

So what about the form assumption of knowledge in terms of declarative and procedural type? Human cognition is by nature not a production system but this reference serves reasonably well to model a great diversity of effects it brings about. This also means it can predict and account for a series of distinct characteristics of human behaviour, especially those that lie within the perimeters of its computational framework, particularly capacity issues and reproductive, automated behavioural elements. Variations in transfer, despite unchanged processing demands and commonality in knowledge requisites (e.g., contextual variations), delimit its expressive capacity (Helfenstein & Saariluoma, in prep-a). In general, cognitive architecture-based approaches to study human cognition serve much better in *describing* psychological functioning than in *explaining* it.

Finally, I do not share the opinion that mental representations vary in the essence of subjective experience between being shallow, deep, concrete, abstract, or schematic. These concepts all depict an extrinsic judgement of how the contents of mental representations *are related to* some physical situation and its properties that we believe to be the origin or reference of the representation.

Thoughts themselves are a *concretization of mind* that significantly vary in contents but do not bear any qualitative variability beyond that. At least I do not know what an abstract thought is. My thoughts are certainly never abstract, or then they all are. The point is that thoughts - as thoughts instead of in reference to something - are all mentally concrete to the beholder.

Applying this viewpoint, humans do not think about Duncker's (1935) radiation problem either in absence of schematic awareness or then in the fashion of the convergence schema; relational information between elements is always inherent to mental representations. People can, however, specifically think, i.e., represent, some structure underlying it. And in doing so, the schematic constellation of the rays becomes the matter they represent, not anymore the radiation problem per se. In a more generalized sense, humans do not think about problems on superficial levels or in a deep manner. Representations have a single set of constituent resources from which they are constructed, but the focus, i.e., what is represented, may change. What also changes is the contents of the constituents thoughts are constructed from and how these are integrated in a representational whole. As will be shown, mental contents are of various kinds. Of particular concern to us is the distinction between those that draw their direct origin from perceivable information, as opposed to being purely mental, i.e., of non-perceivable origin (Saariluoma, 2003). It is the latter kind that plays a decisive role in transfer.

3.3.3 Adopting a content-based approach to the explanation of transfer: On mental contents, apperception, and 'seeing as'

Content-based psychology

Two concepts are of key importance in the conceptualization of transfer presented here. One of them is *mental contents*, the other is *apperception*. Neither of the terms is novel as such and especially the latter has been used in various works throughout the history of psychology and philosophy (Brentano, 1874; Kant, 1781/1956; Leibniz, 1704/1989; Stout, 1896; Wundt, 1896/1922). However, in order to appreciate their specific relevance and meaning in the context of the present thesis their understanding must be seen as derived from Saariluoma's recurrent discussions of a content-based approach within the science of psychology, and empirical implementations of related concepts (Helfenstein & Saariluoma, 2005; Saariluoma, 1990, 1992, 1995, 1997, 2001, 2002, 2003; Saariluoma & Hohlfeld, 1994; Saariluoma & Kalakoski, 1997, 1998; Saariluoma & Maarttola, 2003).

Hence, the content-based approach to the study of psychological phenomena has so far been successfully applied to a variety of research questions surrounding human thinking and behaviour, and its merit has been demonstrated by the above mentioned researchers for the domains of design, architecture, chess playing, and engineering among others. It is reasonable to assume that the content-based approach suits particularly well for the study of transfer in the way the phenomenon is conceived of here, and especially with

regard to context of the current reconstructive purpose. The following considerations shall further substantiate this assertion.

Mental contents

The content concept allows characterizing the essential mental constituents, i.e., the elements, of which mental representations are composed. The essence of the mental contents notion may also be framed as the genuine contents of thoughts, as opposed to some form-derivative, e.g., schemata, or the cerebral substrate for thought. But the use of the content notion in the present thesis should also not be confused with its wide-spread understanding in terms of knowledge or semantic domains and actual (stimuli) matter of a problem, i.e., a learning substance-oriented view (see e.g., Reeves & Weisberg, 1994). Obviously, these are legitimate ways of looking at content but not the decisive one for the reconstructed theory of transfer, which is concerned with the contribution of contents to the construction of mental representations.

Apperception and seeing as

With the notion of apperception, in turn, I refer to the way mental representations are constructed in a teleological mental process by selecting, integrating, and organizing mental contents. Its purpose is to create holistic and subjectively meaningful accounts of experiences; an idea that may be best understandable in the light of the intentionality notion of thought that was propagated by representatives of "Würzburger Schule" in the wake of Brentano's (1874) work. Hence, apperception is seen as a very rich constructivist concept; it is the process by which subjective world encounters do not only get processed to something, but they become experiences of something *as something* (Husserl, 1930/1976; Saariluoma, 1995). As Wittgenstein (1958) implied, the meaning of things depends on their use. And in constructing mental representations we apperceive things as instances of meaning, immanent to their use and role in connexion with other contents.

In apperception the true "language of the mind" is generated, i.e., representations are getting content-full apprehensions of the world through the mind. In doing so, apperception integrates not only mental contents that are inherently related or directly traceable to actively processed sensory information into our mental representations but it adds a dimension of reason or meaning to them. This means that there is an interpretative and enhancing momentum to apperception that goes well beyond that of perception. This qualitative augmentation or addition in apperception (from Latin *ad*-perception), that makes us see things as something is what Husserl (1901/1980) may have referred to as "Überschuss".

A word about "seeing as" and conscious reflection: Not all parts of mental representation are necessarily readily available to conscious contemplation. In fact, it is the very essence of most contents of human thought, such as the *use* interpretation of a certain tool, that they are inherent to the way we see things

in an absolute sense, but it may be difficult to spontaneously elaborate on this. Seeing something as something is not equal to explicitly knowing *of* it in this way. We may, for instance, systematically avoid certain situations in our life and not be conscious of the reason for this, and still it is the contents of our mental representation concerning this situation that make us feel and act in this way.

Percepts and concepts

Generally, the distinction between *seeing* and *seeing as* implicates that there must be more than meets the eye from mental perspective. The simple contention that human thought, and thus the contents of mental representations, entails more than just stimuli-bound information is of course not new. This line of reasoning has a long history that is already reflected in ancient debates between empiricist and rationalist views of Aristoteles and Plato and has brought about the well-accepted distinction between percepts and concepts (Goldstone & Barsalou, 1998; James, 1911; Leibniz, 1704/1989; Locke, 1690; Maritain, 1999; Müller, 1896; Wedin, 1988).

We can all generate mental imagery based on memories, conceive of plans, fashion fantasies, or dream without these elements of representation referring to any actually present form of stimuli. Hence, mental representations are definitely not constructed solely of information that can be traced back to sensory input. This basic testimony is naturally a very crucial prerequisite for cognitive transfer, especially the schema-based type. And indeed, perception-oriented Gestalt psychologists themselves have built their core theoretical postulations around the proposition that humans necessarily represent things differently from how they are.

On perceivable and non-perceivable kinds of contents

A more difficult question arises with respect to the initial origin and nature of the elements of conceptual thought: are they *in principle* perceivable or not, i.e., is all mental content rooted in perception at some time during an individual's learning biography? The answer to this question brings us to an important distinction between perceiv*able* and non-perceiv*able* kinds of mental contents (Helfenstein & Saariluoma, 2005; Helfenstein & Saariluoma, in prep-a; Saariluoma, 2003).

Many constituents of mental representation, i.e., the way we encounter and experience world affairs, are of a profound non-perceivable nature. Emotional valences are a very good example. It is one thing to represent the schema idea of a convergence of rays in Duncker's (1935) tumour problem; it is another thing to see it as a good or bad idea. There are naturally numerous examples of non-perceivable contents in mental representation, such as freedom, moral, hope, importance etc. The radiation just mentioned is another one, and one of the articles in this thesis demonstrates how this fact introduces

an additional dimension to the difficulty of solving the tumour problem (Helfenstein & Saariluoma, 2005).

Hence, not all contents of mental representation can be readily tracked to perceivable information. However, this does not mean that everything that does not exist in reality, but finds representation in our mind, is in principle of non-perceivable nature. The fictitious dragons illustrate this point well. Although dragons, as living creatures in nature, can not be perceived as a whole, much of their representational quality is still composed of perceivable information. These may be lent from various perceptual resources of experience, such as encounters with reptiles and lava spitting volcanoes. In some cases principally non-perceivable objects of human representation may actually emerge almost completely from constructive processes of perception, such as the visual illusion of clouds as UFO's or a mirage experience of a swimming pool in the centre of the desert. A uniting criterion for these aspects of non-perceivable elements in mental representation is that they are not completely detached from perception, but the relationship is very asymmetric: although we can not a priori perceive a dragon in nature we can easily create its physical appearances on the walls of caves, in clay, or as a 3D computer animation.

Schemata and production rules, as vehicles of transfer, belong to the same category, because they can in principle be drawn on paper or symbolically represented in a computational model. In this, I do not want to imply that schemata and other structural derivates of thought have no value in explaining cognition, but they have their clear limitations in explaining human thinking, and in our case transfer, with regard to content dimensions. Both schemata and procedural knowledge are by definition void of content in the sense as it is understood here. Rather, their specific value for cognition is seen either as abstractions or capsules of content.

The role of non-perceivable kinds of contents in transfer

Here, I am therefore more interested in the genuinely non-perceivable kinds of mental contents, and I propagate the view that they play a very essential part in transfer. Non-perceivable mental contents are an essential cornerstone of the human cognitive enterprise in coming to a meaningful understanding of world affairs through seeing things *as* something. This refers evidently to a perspective that is fundamentally distinct from the one common element- and analogy-based transfer conceptions are based on, namely the notion of seeing and the philosophy of "as if" (Vaihinger, 1870/1924), respectively (see also Lakoff & Johnson, 1980).

Because there are so many non-perceivable mental contents conceivable, the focus is on their key quality to give *interpretation*, *meaning*, *use* and *functional value, valences*, and *instantiate roles* of mental constituents in our representation. Those qualities provide the essential contents to human thought, and allow, for instance, for the creation of thought models (Helfenstein & Saariluoma, 2005).

It is very obvious, for instance, that the qualities of the mentally represented dragon that can be rendered as perceivable information do not yet

entail such kinds of mental contents. And, hence, in their absence we could only possess an imagery of a dragon shape but would not be able to apperceive it *as* evil, its existence *as* possible, or its function as being an opportunity for the legendary knight to prove his courage. It is such contents that ultimately enhance the quality of our experiences and determine their value for the way we understand and behave in every day situations. We can not evade their integration into our mental representations, because of their immanence to apperception. And because in the process of constructing mental representation, apperception follows laws of experience, the selection and integration of mental contents is not only by facts but through inherent intentionality susceptible to transfer.

3.3.4 Summing up the content- and apperception-based theory of transfer

Let me reiterate: Transfer, as the relation between mental representations, is delineated by the manner and degree to which novel experiences (i.e., the construction of current mental representations) emerge from the integration of previously relevant mental contents, as well as the experiential and behavioural consequences of this. The mental activity that is responsible for creating such relations is apperception. Taking this viewpoint on apperception, we can thus describe it as the process of understanding by which newly observed qualities of a situation are related to and comprehended on the basis of past experience, i.e., by selecting and integrating mental contents depending on and defined by their contribution value in prior mental representations. Transfer, is therefore grounded in the way we apperceive and understand something by seeing things *as* something, and implicitly, by something *else*. It tells us what contents are relevant, how they should be related to each other and, therefore, what their function is in and for creating meaning as a whole of the experience. Thus, the way humans comprehend current world affairs is intimately dependent on the way they have come to an understanding of earlier situations.

Historic link between apperception and transfer

The content-based approach of placing transfer within the framework of apperception is an essential development, but also firmly rooted in Herbart's (1824-25/1968) and later Lazarus' (1917) and Stout's (1896) views on apperception (see also Eisler, 1904, for a brief overview). Both James (e.g., 1890) and Wundt (1896/1922) appropriated Herbart's idea of apperception for their Associationist accounts of consciousness. But this does not pay the deserved tribute to the fact that Herbart's view essentially envisaged a schema and attitudinal nature of mental representation. He did not, however, use concepts that would anticipate a content-based approach, as it is laid out here. Let us consider this description by James (1899, Chapter 14):

> We *conceive* the impression [i.e., stimuli perception] in some definite way. We dispose of it according to our acquired possibilities, be they few or many, in the

> way of 'ideas' [i.e., thoughts, mental representations]. This way of taking in the object is the process of apperception. The conceptions which meet and assimilate it are called by Herbart the 'apperceiving mass.' The apperceived impression is engulfed in this, and the result is a new field of consciousness, of which one part (and often a very small part) comes from the outer ' world, and another part (sometimes by far the largest) comes from the previous contents of the mind. … The product is a sort of fusion of the new with the old, in which it is often impossible to distinguish the share of the two factors.

Principles of content selection and integration

It is, further, important to notice that mental contents are not selected and integrated into mental representation together with other contents, simply on the basis of them being contents by themselves. There is no valid self-sufficient view on representational contents. The fundamental nature of mental contents must be seen as derived of the way and reasons why they are present in a particular mental representation. Every content element has a sense for being compositional part of a mental representation and related to other content elements in a certain way (Saariluoma, 1990, 1995; Saariluoma & Hohlfeld, 1994; Saariluoma & Maarttola, 2003). It is this reality that explicates the true nature of contents in terms of their contribution value to the construction of mental representations. The analysis of relations among constituents can already be found in the works of Brentano (1874), James (1890), Bühler (1907, 1908a), and Selz (1913, 1922), for instance.

Hence, as transfer refers to the relation between mental representations that emerge from content-based concordance, it is not just the selection and integration of some contents per se that influences the individual's current experience, but the reasons for its selection and manner of integration that arises from the way the content functioned in an earlier representation.

Transfer as disambiguator in apperception

Transfer can essentially work as a disambiguator in apperception. As for the representation of any object, a wide variety of contents may be selected. As any concept can actively entail a variety of different limited sets of attributes and uses in mental representations, it is important to select the currently most appropriate one. What is appropriate depends on the object's function we instantiate in our mental representation by giving it a role in relation to other contents, and on how this concert of uses and functions is believed to serve to bring about the necessary conditions and changes of events for attaining a certain goal. Goals themselves are a special type of content, and thus part of our mental representations. Their relation to other contents, including alternative goals, is commonly expressed in the form of emotion and motivation contents. Their essence emerges from our appraisal of contents constellations in current mental representations as well as their consonance and dissonance with other

goals. Goals as constituents of mental representations are therefore commonly expressed in the nature of emotion and motivation contents.

Often it is enough to change a single content in our mental representation to induce a reconstruction that alters its emotional bearing. In the representation of a killing situation, for instance, we may suddenly see an act not anymore as that of intentionality but accident simply by reinterpreting the use content of the lethal tool. As in a network chain reaction, a multitude of other contents in our mental representation will subsequently accommodate this change in apperception and contribute to a holistic reconstruction. Hence, while actual "transfer of" content can be minimal and very local, its effect, as evidenced in apperception may be very radical.

Comparing the conceptual frameworks

Table 1 expresses the core assumptions about transfer basis and mediation in the discussed conceptual frameworks.

TABLE 1 Core assumptions in modern common element-based and schema-based, as well as the content- and apperception-based theory of transfer

	Theoretical approach		
	Common element-based	Schema-based	Content- and apperception-based
Transfer medium	Production rules (secondarily declarative knowledge)	Relational structure in representation	Mental contents
Cognitive process in transfer	Automated reproduction (secondarily slow compilation of new rules)	Analogical reasoning	Apperception
Key relation-establishing process logic	Elementary correspondence-based automatic reproduction	Coherence-based retrieval, mapping, and inference	Concordance-establishing selection and integration of mental contents based on their use in earlier representations
Key qualitative change in representing	Encapsulation	Abstraction and organization	"Seeing as"

It compares the two traditional common element-based and schema-based approaches, to the currently presented content- and apperception-based theory. Three distinct assertions about the unit or medium of transfer are recognized: production rules, structure, and mental contents. With regard to the transfer mediating process the three theories concentrate accordingly on automated

reproduction, analogical reasoning, or apperception. These differences result in distinct views on the logic of transfer relations. Common element-based theories focus on elementary correspondences; the schema-based approach values the idea of coherence mapping and inference; and, finally, the content- and apperception-based approach introduces the notion of concordance between mental representation as a product of the dynamic selection and integration of mental contents. Related with this, the conceptual frameworks also emphasize very distinct aspects or beliefs about the qualitative nature of representing and knowledge generation. These can be characterized as the encapsulation or proceduaralization viewpoint, the abstraction idea, and the notion of "seeing as".

Types of transfer-relevant mental contents

There are a series of non-perceivable kinds of content that can serve as concordance medium in transfer. In our own investigations of mental contents in apperception-based transfer we have examined thus far thought models in schema and implicit imagery (Helfenstein & Saariluoma, 2005), exposed use and functional value, consistency, plausibility, and intuitive relevance of representational elements (Helfenstein & Saariluoma, in prep-a), and argued for the inclusion of emotional content (Helfenstein, 2005; Helfenstein & Saariluoma, in prep-b). Interests in contents can also emerge from their relevance in particular applied domains such as roles of variables in programming (Sajaniemi, 2002; Sajaniemi & Navarro, 2005), or risky thought models and functional structures in design thinking (Saariluoma, 2002; Saariluoma & Maarttola, 2003).

And in the sense that contents in thinking and their relation to transfer in apperception have naturally always been relevant, and not just with the inception of the presented theory, we can expect that many earlier discussion and experiments about learning and thinking can be examined and explained from this view point. The functionality concept of Gestalt psychologist, for instance, can of course easily be made valuable to the type of content-based research of transfer pursued here (Duncker, 1935; Köhler, 1917; Koffka, 1925). The same is also true for the a wide range of other concepts such as the ideas of sense-making relations in the thought psychology of Bühler (1908a) and Selz (1913, 1922), Festinger's (1957) cognitive consistency theory, Dewey's (1934/1980) anticipation concept, or fallacies (Aristoteles; Bacon, 1620; Mill, 1843; Hamblin, 1970).

3.4 Empirical support for content-based approach to transfer research

Thus far, the advancement of the theoretical reconstruction has been based on foundational considerations of transfer research and the adaptation of a

content-based approach in psychology (Saariluoma, 1990, 2001, 2002, 2003). Obviously, we need to support the reconstructive argumentation also empirically. In doing so, we need to demonstrate ways in which a content- and apperception-based analysis of transfer can indeed augment traditional explanations, possibly resolve controversies between them, and uncover novel aspects to the phenomenon. The rationale for the development of an empirical program was the following:

1 The first major point for the content-based theory to make is to show that there can be variation in transfer that is not predictable within classic paradigms. In the context of arguing against common element approaches and schema-based conception there are naturally at least two versions to this supposition: (a) systematic variation in transfer despite constant common elements conditions and (b) systematic variation in transfer despite constant schematic conformity. The exposure of such variation would essentially support the reconstructive strategy of moving outside paradigms in explaining transfer. It would also hint at the role of non-perceivable kinds of contents in mental representations and their influence on seeing things *differently* despite atomistic and schematic similarities.

2 Another related important challenge is to reliably explain the discovered variation on the basis of selection and integration processes of mental contents in transfer. This would substantiate the actual assumptions, both about apperception and the use of mental contents in mentally representing things; as well as demonstrate their theoretical value for explicating process- and medium-aspects in transfer.

3 Finally, it has been a comparably minor but highly cherished aspiration in this thesis to advance transfer research that can and does incorporate emotional dimensions of cognition. This path of investigation is pursued in a separate article included in the thesis.

These issues are addressed in four original articles that are included in this thesis. Article 1 (in the order of their inclusion) is a review article designed as synopsis to the arguments and findings presented in the advancement of the content- and apperception-based theory of transfer. Articles 2 and 3 provide essential support for variations in transfer when solving a classic schema-oriented problem and under superficially common-element conditions, respectively. Variability is discussed from a content-based view. Finally, Article 4 broadens the view on cognitive transfer by presenting an investigation of affective dimensions of transfer in an applied consumer and user psychological setting.

3.4.1 Article 1

Helfenstein, S. & Saariluoma, P. Reconstructing cognitive transfer. First submitted to Psychological Bulletin. To be resubmitted.

The main contribution of this publication lies with the presentation of an evaluative review of transfer research and the reconstruction of the theoretical foundations for studying cognitive transfer in the form of the content- and apperception-based theory of transfer. It focuses on a foundational analysis of a wide range of empirical studies and theoretical explanations from the field of transfer research in general as well as the insights to the phenomenon gained from content-based point of view. In the course of the reconstructive synthesis (a) the general state of knowledge concerning transfer is examined, (b) a critical assessment of the strengths and weaknesses in past research is presented, and (c) important unresolved issues are revealed. The paper's intention is to direct future research and to provide it with novel content-based concepts so it can yield desperately needed new insights to the phenomenon. The review approach is both historical and cumulative and it explicates developing connections and conflicts between relevant areas. It also integrates transfer research within a greater cognitive scientific framework of human thinking and mental content-based approach to psychology.

3.4.2 Article 2

Helfenstein, S. & Saariluoma, P. (2005). Mental contents in transfer. *Psychological Research, Online First*.

The purpose of this study was (a) to reveal essential variations within transfer for a classic Gestaltist schema-oriented problem, (b) to explain them on mental content based grounds, and (c) to explicate implications of the findings with regard to the postulations of schema-based transfer theories and contrast to a content-based approach.

The experimental task and materials were developed from Gick and Holyoak's (1980, 1983) seminal paper on schema-based analogical transfer, in which the authors adopted Duncker's (1935) classic tumour problem. As characteristic to the schema-based view on transfer Gick and Holyoak's assumed that the abstract structure underlying a primary problem's solution will be applied by participants to solving a secondary or target problem (Reed, 1993). Despite devising a very schema-salient source analog the authors found a surprisingly large amount of transfer failure, and explained this mainly with lack in superficial links and domain barriers.

In so far as the problem was recognized rather as one of lack of spontaneity than incapability, the problems could also lie elsewhere - namely with people's apperception. In two preparatory studies and a series of three experiments this issue was examined further.

At the onset of the analysis, a first tacit assumption, inbuilt into Duncker's (1935) and Gick and Holyoak's (1980, 1983) was revealed. This pertained to the implicit spatial image of ray maintained by the participants. Instead of a presumed homogeneity in participants' beliefs that they look and function like a tightly bundled laser-beam, this kind of representation was found only with a minority. Rays were rather seen as "chaotic", "diffuse", "diverging", and "hard to control".

Additionally, the preparatory qualitative investigation indicated that the confluence of rays may, despite the unique structural properties of this schematic arrangement, be conceived of in a variety of fashions. The conventionally assumed *thought model* has been that of an *additive* integrative effect on destroying the tumour; however this view was not univocally shared by participants. A deviation from this ideal thought model would at the same time also negatively affect the assumption about harm-control of the radiation to the tumour-surrounding tissue; which is the major problem-solving constraint in the tumour task.

The conjecture was therefore, that the differences in how rays and their confluence are apperceived may show significant effects in transfer, especially, because both tacitly assumed representational contents (i.e., the laser-like, compact image of ray and the additive thought model of confluence) are mandatory for solving the tumour problem and for establishing meaningful transfer in the tasks devised by Gick and Holyoak (1980, 1983). The intention was to see whether it is possible to infer differences in apperceiving the ray confluence from participants' judgments of its effects on destroying the tumour and preserving the surrounding tissue.

A similar priming design including primary learning and the transfer judgment task was used for all experiments to allow for comparison between them. Different confluence schema source problems were devised with the objective to induce distinct content selection when representing the spatial organization depicted in them. In addition, half of the participants in each experiment were primed with a pictorial illustration that displayed rays in a compact manner; the other half received a pictorial with a diffuse ray display.

The results of Experiment 1 documented an overwhelming application of the additive thought model to the judgement of effectiveness of ray confluence, but less so with regard to its harm-controlling tendency. Interestingly there were also groups of participants that did not select the additive thought model for representing the ray confluence schema in the tumour task. Alternative thought models were identified as *balancing*, *distribution-based,* and *intermediate.*

By use of the same methods as in Experiment 1, Experiments 2 and 3 generally supported the validity of the balancing and the distribution-based thought models and documented their impact on participants' reasoning in terms of a thought model-consistent shift in how confluence effects are apperceived.

Some priming effects of the ray image could only be found in a comparison analysis of the three experiments, which hinted at an interaction

between the two mental contents. This interpretation can be well accommodated with the apperception model due to its role in integrating activated contents. The small size and inconsistency of the effect may, however, also be explainable on the grounds of inadequate choice of the presentation method.

The research presented in this paper focused on very specific, spatially-related types of mental contents. This delimitation was a necessary consequence of proofing the apperception case against schema-based transfer. As a key result, the paper produces ample evidence for the assertion that structure-oriented concepts of thought alone are not adequate differences in individual behaviour, simply because they do not have the capacity to reveal and explain the selection and integration processes of distinctive contents in mental representation.

3.4.3 Article 3

Helfenstein, S. & Saariluoma, P. Analyzing apperception in transfer. First submitted to Quarterly Journal of Experimental Psychology. To be resubmitted.

The study presented in Article 3 shared its basic rationale with the investigation described in Article 2 but extended the scope of investigated characteristics of mental contents and apperception. Because here, participants did not simply have to judge the effects of a given solution (i.e., the confluence of ray), but to actually develop their own, the focus needed to be on more dynamic issues in apperception.

In order to demonstrate the power of content-based investigation in transfer, and to compare it as effectively as possible to traditional explanations, another previously employed problem solving task was used: The Weigh the Elephant problem (Chen, 2002).

The Weigh the Elephant task involves a limited set of objects that have to be used in a meaningful collective way to construct one of several possible solutions. The main focus of the content-based analysis was therefore on the *use* values people attribute to objects and the way they *bind* them dynamically to holistic representations of a scaling method during apperception. This perspective was obviously very different from the previous accounts of explaining solution behaviour in the transfer task that was based on the procedural concreteness level of the primed method.

The study comprised three experiments with two learning conditions each. The main idea in Experiment 1 and 2 was to disambiguate the activation of use content for different objects and to create a tendency to bring objects into meaningful relations to each other during the process of constructing a solution representation. The basic objects available for solving the target problem remained unchanged in all experiments, both with regard to their pictorial representation as well as to their terminological label. Hence, the transfer was possible under unchanged common object conditions throughout. In

Experiment 1 and 2, the objects were additionally complemented with a single written set of unchanged attributes each.

What was manipulated between conditions was the information about typical utilization of the object in a general sense (Experiment 1) and, in addition, the way objects were embedded in relation to each other in a visual depiction of the scenery (Experiment 2). In both experiments, the aim of use content disambiguation for problem-solving was to increase the probability of employing the provided objects for developing either a boat compression or a hanging balance scaling solution.

The results in both Experiments clearly supported the hypothesis about the dependency of constructing a certain scaling solution on (a) the changing *use* content of the objects, as well as (b) the *dynamic bindings* involved in this apperception process to integrate different object uses in a meaningful way. The validity of this line of reasoning in interpreting the results was essentially supported by the fact that no relevant differences were found between the conditions with regard to attribute-based constraints in the way participants represented the critical objects or the principle plausibility of the two solutions. Hence, common stimuli elements ceased to be common elements in mental representation, bringing up distinct apperception transfer processes. Also static visual schemata representations needed to be reconstructed mentally through accommodating the dynamics in contents with according binding processes.

The third and final experiment replicated essential design elements from the first two, but its focus was more on negative transfer than on conditional variations within unchanged common element conditions. As has been elaborated elsewhere, negative transfer is traditionally of concern for schema-based research, because, in a strict interpretation of the theory, it lies outside the paradigm of the common element postulation (Allport, 1937; Katona, 1940; Singley & Anderson, 1989).

Two conditions were devised, an *inhibiting* condition and a *disorienting* one. To the former group of participants, objects were displayed in an identical manner to that in Experiment 1, but accompanied with discouraging, although not principally obstructing information about their general use; the latter group received the objects additionally visually organized in a solution-inappropriate way.

Results from both conditions showed a dramatic decline in the production of solutions, hence negative transfer was confirmed. Against the background that the problem story and the objects were identical with the previous experiments, alternative explanations for negative transfer from those related to superficially misguided inferences or inappropriate mapping (Goldstone, 1998; Goldstone & Sakamoto, 2003) are needed. This is true especially for the inhibition condition. In the disorientation condition, the failure effect was amplified due to inappropriate visual cues about object relations. The fact that new combinations were formed and novel solutions produced suggests, however, that the effect was not merely one of schemata, but of dynamic functional integration of the objects in use.

In sum, the study presented in Article 3 supported the line of reasoning that mental content-based investigation essentially provides new insights to familiar problems and behavioural effects. In the presented experiments the observed effects are well explainable on the grounds of apperception processes of content selection and representational integration. Both common element- and schema-based explanations are less applicable or invalid because the used experimental manipulation left the relation between primary and secondary learning (i.e., transfer) unaffected in these respects.

3.4.4 Article 4

Helfenstein, S. (2005). Product meaning, affective use evaluation, and transfer. Human Technology, 1(1), 76-100.

The study presented in Article 4 focused on affective dimensions in apperception and transfer. It investigated these issues in the concrete applied context of people seen (a) as consumers, with certain representations of products (mobile phones) in general, and (b) as users, interacting with and evaluating two related devices (emulated mobile phone interfaces). Because the thematic scope of this article and the field-oriented terminology was somewhat different in accentuation compared to this thesis, I will try to refocus and reformulate its rationale and findings to bring them in line with the present aims.

The concept of *product meaning*, as it is implied in the study, emerges from a variety of relevant experience (direct and indirect ones) people make with products. The main point here is that product meaning is a summarization for a variety of mental contents people have in representing a certain product, and that these convey the apperceived uses of the product and its functional relations to the self in a variety of aspects and life situations. These aspects of meaning have been given many tags in consumer psychology research, such as utilitarian, expressive, symbolic, and hedonic meaning (see e.g., Allen, 2000; Allen & Ng, 1999; Bloch & Richins, 1983). Product meaning was measured in a questionnaire prior and unrelated to the actual experimentation to avoid interference with the experimental manipulations, and to allow for the selection of representatives of specific consumer groups.

The second concept used in the article is that of *affective evaluation* of a product in interaction, which depicts the emotional reaction to a device after direct use experience has been instigated. As mentioned earlier, emotions are conative content and as such integrative part of mental representations. When engaged in task-guided use of concrete device, a user will continuously construct mental representations of the interaction situation, which provide the essence and basis for the type of experience and behaviour, respectively. Representations vary naturally in relation to what they represent during use interaction (e.g., the task a user is engaged in to reach a certain goal, representation of the system architecture, or representation of the aesthetic properties of the design) and what mental contents are readily activated to be

integrated into these representations (e.g., contents of general product meaning and earlier representations).

All participants trained on two different successive emulated mobile devices and gave their evaluation of both of these immediately after their use. There were two manipulations inbuilt into the experiment, one within-subject the other between-subject. For all participants the use of the first device was purposely obstructed, to cause disruption in the interaction and possible frustration, whereas the use of the second device was free of obstruction. However, half of the participants were made believe that the two devices are of the same brand, whereas for the rest the brand name changed.

From the common element transfer theory point of view this meant that in the same brand condition there was an important additional common element that was missing in the different brand condition. On schema level, there were however no differences in transfer relations between these two conditions, because the phones (i.e., layout navigation structure, etc.) were identical for all participants.

The essential focus of the study was on emotional content of use experience, and the employed PAD (Mehrabian, 1995) measure allowed for the differentiation of three separate underlying content dimensions: *valence*, *arousal*, and *control*. A content-based approach to the investigation of peoples' affective evaluation of the devices assumes that people engage in integrating contents that stem from the actual interaction with the device (e.g., the experience of task obstruction) on the basis of their general apperception of the devices as members of a product category. In doing so emotions function as holistic indicators of how well the quality of this construction process resonates with core needs.

Generally we found good evidence for a variety of factors that influence the construction of mental representation and the emotional quality it conveys, based on the three measured content dimension. People that emphasize the importance of hedonic qualities in products were more apt in activating negative valences due to interference with the goal attainment task process under obstructed conditions. In addition they were also more intimidated when the second device was of the same brand, which overshadows the fact that there was no instigated obstruction. On the other hand they were also more relieved when the brand changed.

People with a more pragmatic approach to mobile phones and more affinity to investigate and put up with issues of functionality (i.e., high involvement) were not as affected by the obstruction experience with regard to emotional valence, as with regard to the emotional content dimension of control. These being the major content dimensions of emotion for them also expressed best their representation of the second device, which saw a significant increase in the feeling of control.

Common element condition of brand-relation could explain some transfer effects, especially for those individuals who by nature are more holistically (i.e., hedonism) oriented in their judgment of products. In so far as hedonistic views

on products are traditionally correlated with age and gender, effects of these personality factors could also be demonstrated. However, a major factor for emotional experience and transfer of it seemed to be in how people amalgamate their general apperceptions of product (product meanings) with the actual process of constructing mental representations under use conditions. Schema-based transfer explanations could not be made useful for the kind of variations that were found.

3.4.5 Discussion of the empirical validation

There were three major aims in the empirical substantiation of the reconstruction of cognitive transfer by applying the content-based thinking. First it was important to show that for very homogeneous and well-restricted conditions, both common element- and schema-based theories can provide appropriate predictions, but that transfer in most problem solving contexts will display a variability that can only be explicated when the focus of analysis is shifted to mental contents. This point is well substantiated by all articles. We could, for instance instigate significant differences in problem solving in the Elephant task by employing manipulations of conceptual information about object use alone (Helfenstein & Saariluoma, in prep-a). We also found systematic variability in the way the confluence schema was represented in the application to Duncker's (1935) tumour task (Helfenstein & Saariluoma, 2005).

Secondly, the investigations aimed at identifying and describing the mental contents and apperception processes, and explaining the way they influence transfer to bring about the observed behavioural variability. Article 2 clearly explicated the role of *thought models* underlying spatial representations. It also worked on dealing with issues of intuitive, implicit images, but less successfully so. Article 3 added its own set of mental contents and apperception characteristics to the explanation of transfer on content-based grounds. Two major factors were explicated. One is the *use content* of represented elements, i.e., the way we see objects *as* something through their use or functional value the have in relation to others an the goal. The second is *dynamic binding* in apperception, which is inter-dependent with the changes in use contents of elements.

It is natural to assume that there are many other kinds of contents that influence the construction of mental representation under transfer conditions in essential ways. In principle, any kind of content and all aspects of apperception will be relevant in this respect. Types of identified mental contents may hereby be of very general nature (e.g., use of an object) or very specific (e.g., thought model of confluence). Nevertheless, the general point made will not principally change by revealing more types of contents in various applied contexts, it will only augment the strength of the argumentation for it.

Even so, it is advisable to continue this line of research because it is the only valid way to develop the content-based approach and theoretical models of apperception. The choice of focus of future research with regard to content-based transfer may now be conducted in a more application-driven manner.

Article 4 concentrated, for instance, on very distinct kinds of contents, as of a priori decision concerning research focus and target field.

This links to the last point of the empirical agenda, namely the extension of the investigation of transfer research to issues of conation. The study presented was clearly preliminary in this respect but it succeeded in testing some hypotheses with regard to emotional content dimensions that will prove essential for future development of this type of research. In essence, it provides additional issues concerning integration of mental contents in representation, and it does this by explicating its dependency and effect on the generation of emotions in experience. A dimensional approach to the conceptualization of conative content seemed most appropriate. This was true both for the general values incorporated in peoples representations as well as for more focused emotional reactions. Elaborating on these, bringing them in relation to each other, and explaining their role and genesis in apperception will be the task of future research.

3.4.6 Contribution to collaborative research

Articles 1-3 have all been prepared in close collaboration with Pertti Saariluoma. Naturally the adoption of the content-based approach and the introduction of its relevant basic concepts have been inspired by Saariluoma's prior work in this area and are easily apparent across all collaborative papers and this thesis (Saariluoma, 1990, 1992, 1995, 1997, 2001, 2002, 2003; Saariluoma & Hohlfeld, 1994; Saariluoma & Kalakoski, 1997, 1998; Saariluoma & Maarttola, 2003). Saariluoma's (1997) meta-scientific reflections on the method of foundational analysis have further been a distinct motivation and guideline for the pursuit of the reconstructive approach taken in this thesis.

Both, content-based psychology and foundational analysis have been central to our regular discussions and our collaboratively devised plan on how to approach the challenge of resolving theoretical controversies with respect to transfer and how to essentially advance its research. The foundations for the reconstructive work in terms of the review, analysis, and critical assessment of historic transfer research have been laid in a working paper I devised in 2002. This interactive work is reflected in Article 1.

Based on the opinion to address critical issues in past transfer research by adopting its own classic empirical paradigms and settings, we agreed on the choice of Gick and Holyoak's (1980, 1983) task in Article 2. The use of Weigh the Elephant problem (Chen, 2002) for Article 3 was my own initiative. For both papers I then adapted and developed the experimental tasks, materials, as well as the opening observation methods. The experiments were run and supervised by me, and I presented a first program of analysis of the data.

The tailoring of the analysis agenda to our argumentative purpose was critically influenced by Saariluoma's experiences with content-based investigation, our common vision of our research's message, and my intuitions about the potential of the experimentally collected data to reveal essential issues. After devising a first full manuscript of each article on my own,

rewriting was completed in a close collaborative exchange of opinions and formulations. Saariluoma's contributions were essential for the overall argumentative structure of the papers, and therefore the contents of the introduction and discussions. I was responsible for the method and results sections, figures and tables, and I elaborated, edited, and integrated Saariluoma's initiations to bring the papers into an overall rich and coherent form.

4 GENERAL DISCUSSION

4.1 Method of argumentation

The essential structure of argumentation in this thesis arose from the major steps of broad review, critical examination, conceptual exposition, paradigm shift, theoretical reformulation, and empirical substantiation. Figuratively speaking the focus on transfer research and theorizing went first *wide*, then *deep*, then *outside*, and finally celebrated its *homecoming* within a new framework. The logical final step is the current reflection upon this journey.

Reconstruction of transfer has been the main guide and aim of this thesis. Reconstructive stance starts from the foundational analysis of research, proceeds to the assessment of major lines of reasoning instantiated in historic and present conceptual postulations and empirical inferences, identifies their shortcomings and areas of conflicts, provides a meta-theoretical framework and instruments within which these can be addressed and resolved, and finally introduces a new set concepts and of theoretical assumptions that opens the way for a fresh approach to research and theoretical advancement.

4.2 Summary

The thesis puts forward a content- and apperception-based theory of transfer. It adopts its viewpoint and conceptual framework from that of the content-based approach to the study of psychological phenomena (Saariluoma, 1990, 2001, 2002, 2003). Mental contents are hereby recognized as the essential constituents of whom mental representations are constructed. Apperception is the cognitive process that is responsible for the selection of content and their integration into logical wholes of human experience. Transfer, as a mentally evident relation between mental representations, is seen to function as a disambiguator and bias in apperception. In doing so it establishes a concordance that can equally well

function to either induce the construction of goal- and situational appropriate mental representations of world affairs or impair this process. These two aspects are intertwined with each other as part of dynamic content selection and binding processes, and can express themselves in the form of positive and negative transfer.

In the course of the development of the content- and apperception-based theory, as well as its internal and external validation, it was essential to reference its assumptions and explanatory capacity to that of major conceptual traditions in historic transfer research.

Common element-based and schema-based approaches were identified as the main proponents in the way transfer was conceptualized thus far. The major cognitive psychological instantiation of the common element-based view is that of procedural transfer (Kieras & Bovair, 1986; Singley & Anderson, 1985, 1989). It presumes transfer as emerging from performance gains due to elementary correspondences in required knowledge and skills between learning situations. Relatively good support could be found for this interpretation in within-domain contexts where expertise in the form of automated skills is the major determinant of performance. This is true for routine interaction with machinery, for instance, the application domain where the procedural transfer theory was also first developed.

Schema-based thinking about transfer is an heir of the Gestaltist paradigm and has been essentially developed into accounts of analogy- and abstract rule-based transfer that work on the cognitive premise of retrieval, mapping, and inferences (Gentner, Loewenstein, Thompson, 2003; Gick & Holyoak, 1980, 1983; Keane, 1987; Reed, 1993; Vosniadou & Ortony, 1989). Schema-based theories have by nature been more interested in domain-pervading applications and have consequently struggled with findings of failures that were explained on the basis of superficial constraints. Both theories also refer to mental capacity restrictions in transfer, especially when individuals are believed to be required to engage in complex analogical reasoning processes.

Thus, the two theories build on common ground in some of their assumptions, and especially schema-based theories have frequently tried to work towards a fusion of the two views. This has so far not been achieved and the theories have remained partly unaffected by each other (e.g., through the instigation of boarders in application), partly complementary in their resolutions. This situation is clearly not satisfactory, especially because, in the end, transfer can not mean different things.

The experimental work presented in this thesis attempted therefore to explicate the major shortcomings in explanatory capacity of the two theories, and to provide content-based explanations for their blind spots. As was shown, explanations on the basis of mental contents and apperception allow not only to account for phenomena that were neither predictable nor expressible in traditional theories, it can also provide a unifying ground for those types of transfer that are within the scope of conventional description. There are many important mental contents that are not paid enough attention to by adopting

the presumption inbuilt into the conventional notions of elementary correspondences and schematic mapping. Examples for these are thought models, reason-based explanations, and use, as well as the dynamic evolvement and binding of these in the course of apperception.

4.3 Contributions

Considering the long history of psychological transfer research, its firm embedment in widely accepted paradigms of human cognition and behaviour, and the massive number of publications about the phenomenon over the course of the last 100 years, it is no simple task to provide original and genuinely enhancing new insights. I believe that the presented thesis succeeds in doing so and that it can generate important impetus for the advancement of the way we conceptualize and investigate transfer.

Due to its meta-scientific nature, the primary relevance of reconstruction lies in theory development and empirical explication. Transition to practice in applied fields comes secondary to this.

1 *Unification appeal*: The major argument for a content- and apperception-based theory of transfer lies with its essential role to function as interpreter and consolidator of traditional approaches to transfer.

2 *"Zurück zu den Inhalten"*: The thesis significantly contributes to the development, expansion, and validation of applying a content-based approach within psychology and the broader context of cognitive sciences (Saariluoma, 1990, 2001, 2002, 2003).

3 *Differences instead of similarity*: The previous point advocates a return to the careful investigation of mental representations and their construction processes. This may often necessitate analyzing data with respect to the variations and differences we find in human thinking and behaviour, rather than to commonalities and central tendencies. In the history of methodology in experimental psychology this also hints at the paradigm- and operationalization-oriented debates about empirical techniques between the Würzburg School (e.g., Bühler, 1908b) and Wundt (1907).

4 *New frontiers*: There are important areas in cognitive research, and transfer in particular, that have generally been under investigated. Emotions are one example for this. Interests and concepts in this field are still underdeveloped and heterogeneous, and content-based psychology can hopefully make essential contributions to this field in future. Two major predicaments have hampered the study of

emotion in cognitive science. One is the struggle for unified theoretical paradigms that can integrate emotion and cognition. The other is the challenge to develop measurements based on these theoretical assumptions that can effectively be applied to research in order to encourage the advancement of knowledge. As the focus of the presented paradigm on studying human cognition lies with mental contents and apperception, emotions and their genesis in experience need to be formulated by use of this conceptual framework, and measured accordingly. To date, content-based psychology is still in the process of developing its own language to explain these phenomena.

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YHTEENVETO (FINNISH SUMMARY)

Siirtovaikutus- eli transfertutkimus tarkastelee sitä kuinka ihmisen käyttäytyminen riippuu hänen aikaisemmista kokemuksistaan (Ellis, 1965). Tämä tutkimus on kehittynyt voimakkaasti sen jälkeen, kun aihetta koskevat ensimmäiset psykologiset tutkimukset esitettiin 1900-luvun alkupuolella. Kuitenkin tämän alueen tutkimukset hajaantuvat ja teoreettisten mielipide-erojen syitä ei ole riittävästi tarkasteltu.

Tässä tutkimuksessa tehdään ensin laaja katsaus siirtovaikutustutkimuksen eri suuntauksiin ja näkökulmiin. Tämän katsauksen päämääränä on a) siirtovaikutustutkimuksen tyyppien tarkastelu, b) tunnistaa tutkimusalan perinteiset sovelluskohteet, ja c) analysoida tutkimusalan suhdetta muihin psykologian alueisiin. Katsauksessa tutkimuskohteet eritellään ja samalla selvitetään millaisissa olosuhteissa transferia tapahtuu, mitä informaatiota sen aikana siirtyy, ja kuinka tämä informaation siirtyminen välitetään oppimis- ja transfer tilanteiden välillä. On tärkeää, että näitä perustavia kysymyksiä ja niihin annettuja monimuotoisia vastauksia analysoidaan moniulotteisesti ja teoreettisten traditioiden kirjo on syytä ottaa kokonaisuudessaan tarkastelun kohteeksi. Tästä lähtökohdasta väitöskirja rekonstruoi kokonaisnäkemystä siirtovaikutuksesta.

Rekonstruktion ensimmäisessä vaiheessa tuodaan esiin kaksi traditionaalista mutta osittain ristiriitaista näkökulmaa. Nämä ovat yhteisiin elementteihin perustuva lähestymistapa (common element based approach), jossa siirtovaikutus selitetään atomististen elementtien pohjalta, sekä skeemapohjainen lähestymistapa (schema based approach), jossa siirtovaikutus selitetään skemaattisten rakenteiden samankaltaisuuden pohjalta. Ensinmainittu traditio muotoutui Thorndiken ja Woodworthin (1901a, b, ja c) uraauurtavien tutkimusten pohjalta, ja sitä voidaan kutsua nykyäänkin muodikasta termiä käyttäen konnektionististiseksi (Connectionist). Tämä traditio johti ns. identtisten elementtien transferteoriaan (identical elements theory of transfer), jota Singleyn ja Andersonin (1985, 1989) kognitiivisia arkkitehtuureja ja produktiosysteemejä koskevat tutkimukset ovat edelleen kehittäneet.

Skeemateoreettinen traditio on saanut alkunsa Juddin (1908) identtisten elementtien havaitsemista koskevasta kritiikistä ja hahmopsykologisesta tutkimuksesta (esim. Katona, 1940; Wertheimer, 1945/1959). Tässä ajattelutavassa ydinkysymykseksi nousevat mentaalisten representaatioiden abstraktit ja holistiset ominaisuudet, jotka tekevät mahdolliseksi transferin tulkitsemisen rakenteellisten vastaavuuksien ja analogisten päätelmien pohjalta.

Tämän tutkimuksen ydinongelmaksi on noussut se, että kaksi selittävää lähestymistapaa ovat joissakin suhteissa toisiaan täydentäviä mutta toisissa keskenään ristiriitaisia. Tutkimusalalla käydyn viimeaikaisen keskustelun kohteena ovat olleet representaatioiden pintarakenteiden samankaltaisuudet ja syvärakenteiden rajaehdot (esim. Goldstone & Sakamoto, 2003; Holyoak & Koh,

1987), automaatio ja spesifisyys vs. yksityiskohtaisuus ja yleisyys (mm. Gott, Hall, Pokorny, Dibble, & Glaser, 1993; Pennington, Nicholich, & Rahm, 1998), sekä situationaalinen siirtovaikutus (e.g., Anderson, Reder, & Simon, 1996, 1997; Cobb & Bowers, 1999; Greeno, 1997).

Kasvava kiinnostus kognitiiviseen transfertutkimukseen on johtanut siihen, että on välttämätöntä sekä vahvistaa teoreettisten kysymysten käsittelyä että empiiristä tutkimusta. Ratkaisuna teoreettisiin ongelmiin esitetään tässä tutkielmassa sisältöpohjaisten psykologisten käsitteiden soveltamista siirtovaikutustutkimukseen (Saariluoma, 1990, 2001, 2002, 2003). Mentaaliset sisällöt ja apperseptio tulisivat näin selittämään siirtymisen sisällön (transferoitumisen kohteen) ja siirtymistapahtuman (transferprosessin) välistä suhdetta. Tämä ajatus on muotoiltu nyt esitettävässä sisältö- ja apperseptiopohjaisessa siirtovaikutuksen teoriassa (content- and apperception based theory of transfer).

Kriittiseen rooliin nousevat ei-havaittavissa olevat mentaaliset sisällöt, jotka on integroitu representaatioihin apperseptioprosessin aikana. Mentaaliset sisällöt kuten objektien havaittu käyttötapa tai monimutkaista todellisuutta selittävät mallit, saavat meidät näkemään asiat jonakin ja näin niillä on ratkaiseva selitysarvo tarkasteltaessa tietoisuuden prosesseja transferin aikana.

Tämän väitöskirjan kokeellisessa osuudessa uuden teorian pohjalta on kokeellisesti demonstroitu uuden teoreettisen viitekehyksen avaamia empiirisiä mahdollisuuksia. Empiirisiä tuloksia esitellään ja pohditaan neljän alkuperäisartikkelin puitteissa. Niissä on osoitettu, että valittu lähestymistapa avaa uudentyyppisiä kokeellisia perspektiivejä transferilmiöihin. Uudet oivallukset on formuloitu erilaisten mentaalisten sisältöjen dynaamisina keskinäisinä riippuvuussuhteina (kuten objektien tiedostettu käyttö tai ajatusmallit) ja niiden sidoksina kokoaviin esitystapakokonaisuuksiin apperseption aikana.

Konkreettisten empiiristen löydösten lisäksi tällä tutkielmalla pyritään kontribuoimaan meta-teoreettisesti ja metodologisesti siirtovaikutustutkimukseen sekä kognitiiviseen tieteeseen yleensä. Tutkielma ehdottaa olennaisia uusia elementtejä sisältöpohjaiseen lähestymistapaan (Saariluoma, 1990, 2001, 2002, 2003). Niiden pohjalta voidaan pyrkiä systematisoimaan transfertutkimusta. Tavoitteena on myös stimuloida tutkimusta, joka integroi erilaisia transferin psykologisia ulottuvuuksia yhteen selittävään viitekehykseen. Tämä liittyy erityisesti kognition ja tunteen yhteensovittamiseen. Ehdotettua teoreettista viitekehystä on aihetta edelleen kehittää jäsentämään tutkimusta, valloittamaan uusia alueita, ja laajentamaan siirtovaikutustutkimuksen ulkoista validiteettia ja tansfertutkimuksen vaikuttavuutta.