EMOTION AND MOTIVATION IN LEARNING:

CURRENT RESEARCH, FUTURE DIRECTIONS, AND PRACTICAL IMPLICATIONS

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Abstract. Emotion and motivation are fundamental to learning, something that is well illustrated in the large body of research that these topics generate. However, because of the divergence of theoretical approaches and preferred empirical methods, the nature and the interrelatedness of emotion, motivation and learning, remain controversial. This review surveys both controversial and consensual issues with a focus on basic research on the involvement of emotion and motivation in different modes of learning, among them Pavlovian and instrumental conditioning, and social learning. Special attention is given to the mechanisms responsible for assigning stimuli, events, and behaviors, their emotional value and how this affects subsequent behavior in both experimental and in real-world applications. In addition, explicit (declarative) and implicit (non-declarative) aspects of the learning process are discussed. Although, relevant research is drawn from different levels of analysis, links between levels are emphasized and, when feasible, related to models derived from evolutionary theory. Throughout the paper, each reviewed theme is followed by a number of questions that address important issues for future research. Finally, it is argued that a more systematic approach is needed to better integrate basic research on emotion, motivation and learning with practical applications. Four research-topics that illustrate promising avenues for further integration are presented and discussed.

1. INTRODUCTION, AIMS, AND OVERVIEW

The study of learning, emotion and motivation is profoundly intertwined. It is hard to imagine one without the presence of the others, at least in some form and to some degree. Emotion, and the closely affiliated notion motivation, gives reason, content and directionality to the learning process. They provide some of the basic components on which learning depends. As scientists have come to realize that affective variables are omnipresent in the learning process, regardless of level of analysis, a wider range of approaches have been implemented to better understand their impact. This endeavor has been aided by the development of a new generation of techniques for both data sampling and experimental manipulations, as well as by new theoretical advances, such as models derived from evolutionary theory.

While research on learning traditionally was (and to some degree still is) divided between those working within a behaviorist paradigm using animals, and pedagogists and organizational psychologists studying humans in specific applied settings, psychologists interested in basic human learning have been occupied with what has been termed memory research. However, over the last twenty years, there has been a pattern of convergence of theoretical and empirical approaches originating from research on basic mechanisms in humans and other animals. The progress is slow, but time is taken to avoid compromising on the specificity of the research questions asked. Since the beginning of the 1990's, methodological advances have significantly facilitated this move into a more interdiciplinary research culture. Still, we are

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far from an ideal state of cross-fertilization of knowledge gained in different fields. While much progress is seen in basic sciences in this respect, the integration of basic findings into applied research and practice has been severely protracted.

This report sets out to review current research on the role of emotion, and to some degree motivation, in learning. With this in mind, it aims to single out fruitful lines of investigation, as well as individual issues that need further attention, in different research traditions and on different levels of analysis. An additional goal is to target specific topics that seem especially promising to explore in the pursuit of integrating knowledge gained in basic learning science with research in educational science and, in the extension, with practical applications in education. However, it should be remembered that the latter is a field with almost no established paths of investigation and very few guiding directions to hold on to. Nevertheless, over the last years an impressive body of new research on learning, emotion and motivation display many promising avenues for further integration and an exciting time lies ahead for those who join the pursuit.

A number of new perspectives on learning have emerged over the last decades. Three perspectives stands out as particularly important for the understanding of the role of emotion and motivaton in the learning process: The evolutionary, the cognitive and the social perspectives. These perspectives will be recognized throughout the sections of this report. I start by briefly introduce them below.

(a) The Evolutionary Perspective. Traditional theories have perceived learning as a general-purpose mechanism equally applicable regardless of task or context. Although there are still local pockets of this belief represented in the scientific community, most researchers agree on that learning is a label that covers a host of more or less specialized capacities that are constrained by both the surrounding context and the hard-wired architecture of the human brain. The burning issue is rather how "high" in the cognitive/emotional complexity these constraints reach in humans.

Emotion and motivation have a particular status in an evolutionary perspective. Both factors are centered in the phylogenetically oldest functional systems of the brain, but influences learning of all degrees of complexity, from simple motor learning to the acquisition of abstract rules and concepts. Research over the last years has continued to explore known domain- and stimuli-specific learning effects and provided them with reasonable accounts of their evolutionary origin. In addition, evolutionarily creadable scenarios have inspired a new generation of scholars in their search for environmental dimensions that may predict other learning effects. However, seemingly paradoxically, another emerging line of research has offered strong evidence against the nativist assumption and provided a far more plastic interpretation of the basis of human learning.

(b) The Cognitive Perspective. Since the seminal work by Rescorla & Wagner in the 60's, the understanding of the cognitive components of the learning process has advanced significantly. The focus on expectancies (both confirmed and violated) continues to inspire emerging models of predictability of emotionally significant outcomes. In addition, partially differentiated processes are found to underlie reward expectancy and reward consumption. Other lines of research have tried to disentangle explicit (conscious/verbal) from implicit (non-conscious/non-verbal) aspects of learning. Related to this, fueled by findings of a partial independence of emotional from cognitive components, and supported by recent discoveries in neural science, dissociations between cognitive expectancies and the emotional components of learning are currently one of the most studied phenomena in learning, memory and emotion research.

(c) The Social Perspective. Starting with Bandura (e.g. Bandura & Walters, 1963), research has been increasingly sensitive to the social context in which learning occurs. Several scholars have claimed that learning is a fundamentally social activity (e.g. Reder & Klatzky, 1994). Learning through, for example, observation and instruction in a social setting has proven to facilitate learning both via direct emotional influence and, more indirectly, by modulating motivational factors. Recently, research on social and emotional factors has boomed as new discoveries of the underlying neurocognitive foundations of social perception and cognition in both human and non-human primates, such as the discovery of "mirror neurons", have given support to earlier assumptions. Our social mileu is inherently valenced and it provide us with some of the most influencial incentives to learn.

These three basic themes comprise many of the aspects discussed throughout this report. In its second section, the multi-disciplinary character of the notion "learning" is introduced and some general controversies surrounding its nature are presented (2). Then, basic research on emotional and motivational principles are surveyed and their influence on learning is discussed (3). Next, the many ways in which stimuli and events acquire their emotional significance are addressed. First, the focus will be on Pavlovian conditioning (4), followed by a section on the neural substrates differentially involved in two aspects of emotional learning: explicit (declarative) and implicit (non-declarative) learning (5). Then, research on a variety of social routes to learning are reviewed (6), followed by a section on evaluative conditioning and implicit measures (7). Subsequently, motivational aspects are discussed in conjunction with instrumental conditioning (8) and research on the processes that are involved when incentives exert their influence on a neural, cognition and behavioral level (9). Finally, the ways basic research on emotion/motivation and learning can be integrated with practical applications (especially in an educational setting) are discussed and four specific research-topics are outlined to illustrate promising lines of research in this "integrative" spirit (10). In the last section, the reviewed research, and the highlighted questions for future research, are summarized (11).

Unfortunately, as reflected in this review, most contemporary research on learning and emotion, especially in cognitive neuroscience, focuses on aversive conditioning. Although many of the components underlying aversive and appetative (reward) learning may be similar, also important differences are reported. However, there are now signs of that a new emerging field of reward learning with tight links to other fields, such as addiction research and economics, is being established at various universities and institutions.

In this review, research is presented that has predominately been gathered from psychology and cognitive neuroscience. Selectivity has been seen as a virtue, but not a dogma. Fields, such as the molecular biology of learning, machine learning, and the computational approach to learning, are not represented in this review. Although, the neuro-imaging literature will be referenced, anatomical data will be left out as long as it does not directly pertain to more functional questions[2].

2. THE MANY FACES OF LEARNING

2.1 *In Learning Science, There is Something for Everyone*

"Learning" is a notion that has surfaced within most research and applied fields that are concerned with change and development in humans and other animals. In its most generic sense, it refers to the process of attaining and incorporating information in oneself – adapting in response to a changing world. Throughout the centuries, depending on the current theoretical trend, different meanings have been attached to the concept, and along with changing definitions, the claimed appropriate level of explanation has shifted. For example, as long as "learning" was framed solely in terms of behavior, there was little effort in searching for neural explanations and cognitive components. Uncompromising theoretical convictions, such as behaviorism at its peak, certainly narrowed the scope of investigation and consequently hampered the explanatory expansion of psychological science for a few decades. However, on the bright side, the enormous body of behavioral data that was produced by carefully developed, and experimentally well tested, learning protocols are still of great value. An analogous argument could be made about the influence of other strong theoretical approaches to learning.

2.1.1 The Need for Interdisciplinarity.

While there seldom has been a scarcity in the supply of coherent theoretical accounts of learning (e.g. Behaviorism, Ethology, Cognitivism, Constructivism and Genetic Epistemology), empirical evidence have only recently begun to play a decisive role in the selection of successful theoretical accounts of what learning is, how it works and why it works. Successful accounts have often gained their power by integrating compatible features from different levels of explanation into a broader evolutionary framework (Churchland & Sejnowski, 1992, Sperber, 2003). However, for historical and practical reasons, the artificial division of academic faculties has made the bundle of adaptive mechanisms - what we call learning - a highly scattered field of research. In this plethora of research traditions and methods, the delineating boarders have aligned themselves with different levels of explanation and theoretical inclinations rather than the adaptive challenges that materialized the selection of various learning mechanisms (Cosmides & Tooby, 2000). Consequently, ethologists, neuroscientists, psychologists and educational scientists might study the same phenomena without capitalizing on knowledge gained beyond the institutional boarders. Needless to say, there is a great need of improvement. To this end, a seriously minded interdisciplinarity seems to be necessary, although not sufficient.

As was noted above, a complete, or at least, a better, understanding of the mechanisms underlying learning presupposes different levels of analysis and needs to ensure that theories proposed at one level are compatible with theories at another level. This view makes a strong case for an interdisciplinary approach, where the research problems of interest are in focus and evidence from various fields are brought together in the pursuit of a coherent understanding of the phenomena (Sperber, 2003). Again, although such an integrative approach is gaining terrain in contemporary research both in psychology and the cognitive neurosciences (Gallistel, 1995; Shepard, 1987; Cosmides & Tooby, 2000; Kappas, 2002), the accelerating specialization in the many subfields of learning research appears to pull in the opposite direction - enlarging the gap between the fields. This might however be a hasty conclusion. The deepened knowledge provided within these specializations, spurred by new techniques, often supplies important parts to the total understanding, such as common denominators for

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[2] The importance of the rapidly developing field of brain imaging should be taken seriously. Almost daily, new techniques (both hard and software) are presented, which advances the capacity to view the living, working, brain with a high temporal and spatial resolution. Many researchers believe that these new techniques, most prominently Functional Magnetic Resonance Imaging (fMRI), soon will help to redraw the anatomical map of the human brain on the basis of its functional properties (N. Rubin, personal communication, November, 2002).

human and non-human learning mechanisms. Still, it might be worthwhile to seriously consider a more programmatic framework to the science of learning, guided by recommendations for how to communicate and integrate research conducted on different levels (e.g. neural, cognitive, behavioral, social and distributed[3]) on different creatures (e.g. human and non-human animals and artificial systems), and with different methods.

2.1.2 Learning - at the Center of Controversy

Many of the main controversies that have riddled the study of human behavior and mind - often overshadowed by the antagonism between nativism and empiricism (the “nature versus nurture” issue) - have been particularly polarized in the research literature on learning. One cherished battleground pits proponents of a domain specific against those who endorse a domain general view of human cognitive/emotional endowments. Although it is fair to claim that most researchers today would subscribe to the view that learning does not consist of a small number of mechanisms that are generally applicable to all situations and to all kinds of information (Gallistel, 2000), it is a heated question how “high” in the cognitive/emotional complexity these constraints reach in humans. For example, theorists such as Barkow (Barkow, Cosmides & Tooby, 1992), Cosmides and Tooby (2000), and Pinker (2000) propose that there exist a number of computational learning rules that are disposed to operate on complex social representations and linguistic meanings. Other, more careful nativists, limit their claims about hard-wired computations to govern the processing of simple emotional and social cues (e.g. LeDoux, 1996 and Öhman & Mineka, 2001) and certain abstract primitives, such as basic numbers (e.g. Carey, in preparation). Again others, propose a more constructive approach to learning (for example, Elman et al., 1996; Quartz & Sejnowski, 1997)

Closely aligned with this controversy is the division between those who stress the rigidity in the design properties of the evolved set of prespecified learning mechanisms (Barkow et al 1992; Gallistel, 1995, 2001; Marler, 1991; Pinker, 1999, 2000) and those who emphasize their plastic qualities (Elman, 1996; Balaban, 1998; Christensen, 2000; Montague et al., 1995; Patel & Balaban, 2000, and Quartz & Sejnowski, 1997). Often, domain specificity is proposed in conjunction with an assumption of rigidity. Another camp, not directly affiliated with neither the nativist, nor the constructivist approach, describes learning in terms of a continuous elimination of pre-existing associations and is represented by selectionist neuroanatomists such as Edelman (1987), Kuhan et al. (2000) and Rakic et al. (1994).

It is interesting to note that current research produces strong evidence in both the nativist and the empiricist/constructivist direction. Parallel to the discovery of new specialized brain circuits (across species) supporting the nativist assumption, other findings, cited by the neural constructivists, demonstrate a considerable plasticity of learning functions and their neural substrate. The most striking plasticity-effects are reported in studies that target the immature cerebral cortex[4]. An immense aim for the emerging field of cognitive neuroscience is to specify the relationship between anatomy and function and the constraints they pose on each other[5]. A complicating factor in this pursuit is that the learning device itself is modified as a result of the interaction between organisms and their environment (Quartz, 1999).

2.1.3 An Evolutionary Framework

Regardless of how one portrait the interaction between biological and cultural influences on learning, it is advantageous to keep the evolutionary meta-theory in mind (Öhman, 1986). It provides a broad framework for understanding the many phenomena that make up the notion of learning, from molecular mechanisms of memory consolidation to the learning of associations between abstract concepts. It also gives us a way of linking the proximate learning mechanisms, such as the motivational drive for reward at any particular point in time with the ultimate mechanism, which is stated in terms of the maximization of inclusive fitness over evolutionary time. In this perspective, the genes that most successfully optimized the proximate causes of our behavior by “…building into us the appropriate reward and punishment system and the appropriate rules for the operation of the system.” (Rolls, 1999, p. 7) were the ones that were selected and, thus, the ones that guide our learning.

Although the content of what is learned today might be very different from the knowledge that our past ancestors acquired, the basic mechanisms for learning are the same. Still, both biological and cultural evolution has utilized these basic mechanisms to form new strategies. For example, the capacity to learn the meaning of symbols, such as language, may illustrate how biological evolution used existing building blocks to produce a new, advantageous, trait (Balkenius et al., 2000; Deacon, 1997). However, the idea of a bi-directional impact of culture and biology over the course of evolution in terms of language learning has been interpreted in different ways. For example, in

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[3] Naturally, there is no specific number of levels of explanation with relevance for learning and emotion that can be apriori decided on. Form example, Griffiths argues convincingly for four levels of explanation only in the biological domain (Griffiths, 1997).

[4] For a lucid overview of the current state of research on cross modal plasticity and brain function in both cortical and sub-cortical areas, see Bavelier & Neville, 2002.

[5] A recent account of how modularity can be successfully married with plasticity is delivered by Geary and Huffman (2002).

reminisce of the discussion earlier, some argue that this interrelatedness has equipped humans with a hard-wired language acquisition device (Pinker & Bloom, 1990), while others argue for the emergence of special predisposition to learn symbols (Deacon, 1997). In addition, human culture has realized an infinite set of ways of using our external environment as a distributed arsenal of learning resources (Hutchkins, 1995). However, in spite of these developments, the ultimate goals, as well as the basic mechanisms that serve these ends (including emotions and motivations), are unchanged and henceforth the importance of an encompassing evolutionary framework (Cosmides & Tooby, 1994).

We know about the design of the brain that phylogentically newer functional parts of the brain have been "laid on top" of older ones, implying that a different connectivity exists within and between functional units (Damasio, 1999). Although, the level of hard-wired expertise of different proposed functional units has been vigorously debated, cognitive neuroscience has provided many candidates of such brain areas. One example is the role of the richly interconnected part of the temporal lobe, called amygdala, which has claimed a reputation as necessary in aversive conditioning (Aggleton, 1992). An unknown number of distributed neural connections link the input to, and the output from, cognitive operations from different sites and provides a picture of a richly interconnected neural network that still contains specialized functional units.

Naturally, although learning mechanisms, delineated by science and helped by folk-psychological labeling, sometimes seem discrete on a behavioral level, there is no guarantee that we will find a similarly neatly matched neuro-cognitive correspondence. However, as later will be discussed, there have actually been some recent advances in the search of well defined detailed neural mechanisms that parallel the classical learning mechanisms described by earlier models solely on the basis of animal behavior. For example, the discovery of dopaminergic cells that behave in a manner that corresponds to what was predicted by the Rescorla and Wagner (1972) model of classical conditioning. These findings will be discussed in section 9.

2.2. *Issues for Future Research*

More attention is needed to isolate the contributions of phylo- and ontogenetic constraints in both the developments of learning mechanisms and the representations that these mechanisms are working on. By virtue of its unique role in the learning process, its genetic dependence, as well as the comparably ease with which it is controlled, emotion is well suited as a measure in this pursuit.

In the light of the apparent paradox posed by seemingly incompatible evidence, produced by both the nativist and the constructivist accounts of learning (see, Geary and Huffman, 2002, Markus, 2001), more theoretical models are needed to guide further empirical investigation.

A greater effort is needed to better understand how cognitive strategies modify and build on basic learning mechanisms and emotional (often non-verbalized) processes in order to achieve motivated goals.

With the help of new available techniques for imaging the living and learning brain, one of the most central questions for the emerging neuroscience is to localize the communication between functional neural circuits.

3. EMOTION AND MOTIVATION

3.1. *The Ties to Learning and Beyond*

Without emotion and motivation there would be no learning. Emotional states are integral parts of the adaptive process of learning, which includes attaching value to objects and events (both outside and inside oneself), based on a set of needs. However, as with learning, the content of the notions “emotion” and “motivation” are far from unanimously agreed on, which should come as no surprise if one considers the argument that man made psychological concepts often carry a greater or lesser arbitrariness with them. In other words, it is not easy to “carve nature at its joints”, at least not with a tool, such as language that has been developed to handle far more pragmatic issues.

In short, emotion and motivation relate to internal states that are relevant in the management of goals. For example, motivation has been defined as modulating and coordinating influence on the direction, vigor, and composition of behavior (Shizgal, 2003). In line with this reasoning, emotion is seen as an evaluating response of an event as relevant to a goal; it is positive when the goal is advanced, negative when the goal is impeded (Oatley, 2003). Thus, it has been argued that the key function of emotions in a learning perspective is to decouple the individual from the necessity to respond unconditionally (Scherer, 2001). As will be discussed below, emotions also embody a crucial part of the learning process by influencing the associations that are formed between stimuli, their combinations and behavioral responses. Whereas the impact of emotion is observed at every given moment, the importance of motivational variables is better discernable in the pattern of behavior over time (Rachlin, 2002).

Since emotion and motivation can be conceptualized as internal states in the organism that significantly mediate learning, they also constitute two variables that can be externally manipulated in order to investigate different aspects of learning processes in action. It is therefore not surprising that research on these topics provides us with a steady stream of knowledge on how and why learning works, and the role of emotion and motivation in the process. Moreover, as will be apparent in the following, these internal states, while situated in a steady feed-back loop between the individual and the external environment, are of great importance for any interdisciplinary project such as that which tries to link basic experimental research on human learning with more applied interest (e.g. Izard, 2002). It is through the impact of emotion and motivation, infants, students and adults learn about the world and how to navigate in it, regardless of it being physical, social or cognitive nature in nature.

Because affective aspects are crucial in the learning process, it is important to review the major approaches that have been taken to the study of emotion. What perspective is taken on emotion and its functions also dictates what questions are being asked about learning. There are many ways emotion can be subdivided and subsequently assigned different roles in the learning process. Below, I will outline a major division between two different perspectives on emotion.

3.1.1 Discrete versus Continuous Emotion

Since Darwin (1872/1998), researchers have attempted to specify a certain number of discrete emotions. Encouraged by the findings of anthropological psychologists, such as Paul Ekman, in the late 1960s, six so-called basic emotions have been proposed and thoroughly investigated by mainly psychologists. Affective states are supposed to be reflected in a specific set of facial expressions.

Whereas some have stressed the sharp boundaries between emotions (e.g. Ekman & Friesen, 1971), others have tried to understand the partly overlapping components of such emotions (e.g. Panksepp, 2000, MacLean, 1990). For example, in the view of investigators, such as Pankskepp (2000), there is a group of affective programs on a basic level that is in need of a fixed taxonomy. Again, others have argued the "basic emotion"-stance is inherently flawed and even "quasi-moralistic", without enough empirical support across cultures and species (for example, Fridlund, 1994; Russel,1994, for a similar view, see also LeDoux 1996 and Rolls, 1999). This perspective argues that no discrete lines can be drawn between different emotions. Instead, emotion is framed as a continuous phenomenon consisting of an infinite number of overlapping behaviors and cognitions that are used by both evolution and the individual to manipulate the social environment. This approach is compatible with both the behavioral ecology view that describes emotions in terms of manipulative signals that are the result of an evolutionary arms race of Machevellian intelligence (Griffin, 1992, Stomp-Dawkins, 1986), and the approach taken by many cognitive neuroscientists who measure emotions along continuous dimensions, such as the approach versus avoidance spectrum (e.g. Davidson & Hugdahl, 1995).

The search for discrete emotions has extended into the central nervous system, and there are some studies that highlight specific brain areas as selectively involved in the processing of different emotions (see Calder et al., 2001, for a review). However, a recent meta-analysis ranging over more than 50 brain functional brain imaging studies on emotion lends support to a prediction derived from the non-discrete view (Phan et al., 2002). According to this report, the brain seems to be sensitive to dimensions other than those specified by a number of basic emotions. Rather, according to Phan and colleagues, the neural patterns of activation in emotional tasks are mediated by social versus non-social, implicit versus explicit and valence bound factors. Of course, one can always argue that the dividing lines between different basic emotions are better understood by other psychological or physiological measures than functional brain imaging. At least, they might not be expected to be easily delineated within the brain (Rolls, 1999). Moreover, trying to prove that there are no discrete emotions in the brain seems as questionable as attempting to prove the null-hypothesis. In addition, as mentioned earlier, there are also a few reports of isolated brain activations that are correlated with specific emotions, most notably fear and disgust (e.g. Damasio et al., 2000).

Rolls's (e.g. 1999) stance on the nature of emotion is a good example of the dimensional view on emotions. It is of specific importance in this context since it provides a coherent and testable theory of the intimate relationship between functional emotions and learning mechanisms. Although the basis for Rolls's framework is cast in a behaviorist mold, it allows for evolutionary theorizing, a heavy emphasis on neural data, and the inclusion of cognitive constructs. According to Rolls, emotion can be represented as a two-dimensional system of reinforcement contingencies. One axis depicts a gradient ranging from the presence of punishment (negative reinforcer) to the presence of reward (positive reinforcer). The other axis symbolizes the absence of punishment and reward. The intensity is then increasing away from the center. Most emotions can then be conveniently located in this space and subsequently defined in terms of the presence and absence of reward and punishers. For example, a present reward might cause an emotion that is culturally labeled as either pleasure or ecstasy, depending on its degree of intensity, while the absence of a punisher can be characterized as, for example, relief. The obvious advantage is a strictly functional terminology of the underlying dimensions where the delineation of particular emotions is left to an analysis of folk psychological labeling.

Recently, other researchers, equally hesitant to accept the basic-emotion approach (and equally willing to design clever experiment to support their claims) have suggested that expectation versus receipt of reward/punishment are two other fundamental components of emotion to take seriously. These “fundamentals”, together with valance and arousal, then constitutes an alternative set of basic emotional primitives (O’Doherty, 2002)[6]. It is interesting to note that not only do these putative dimensions make psychological sense, each one of them are also supported by activations in distinct areas of the brain. The next step appears to be to consider the interaction between these fundamental components of emotion (Small, 2002). It will be an intriguing challenge to make sure that these interactions remains psychological or behaviorally meaningful, as well as anatomically valid.

3.1.2 Decoding the Emotional Value

Rolls (1999) has argued that, in order to understand brain mechanisms of emotion and motivation, it is necessary to understand how the brain decodes the reinforcement value of primary reinforcers, such as sex, food and social recognition, and in the extension, reinforcers of a higher magnitude (i.e. grades and money). This evaluative process, performed by the brain, is necessary in order to determine whether a previously neutral stimulus is associated with reward or punishment and is therefore a goal for action. For the cognitive system to work adaptively, different rewards and punishers have to be evaluated and compared in order to make advantageous decisions. The question is how this is done.

In primates, the areas of the brain that are heavily involved in the evaluation of the emotionally significant stimuli and events, have undergone a comparatively big change over the course of evolution. More specifically, the temporal lobes and areas in the frontal cortex, such as the orbito-frontal cortex (OFC), are enlarged and are argued to support a highly complex analysis of emotionally relevant information coming from outside and inside of the body (e.g. Rolls, 1999; Damasio, 2003). By virtue of its rich connections, with both other cortical and sub-cortical areas, it has the capacity to process both stimuli-bound features and abstract representations. The OFC is thus argued to comprise a crucial center for the conversion of reward and punishment related features into a “common currency”. This “currency” then serves as the basis for the selection of the appropriate behavior, as well as for the acquisition of new behavior (Rolls, 2000). In this way primary reinforcers can be evaluated and weighted against rewards of higher orders. If one believes Rolls, this is, for example, the way the value of submitting one self to social and conventional norms can be evaluated in relation to the potential value of acting according to one’s immediate urges (see also the discussion on delayed gratification in section 10).

Another perspective on the nature of emotion and how it influence learning and stimuli evaluation, which has gained an increasing attention recently, is proposed by Antonio Damasio and his colleagues (Damasio, 1994; Bechara & Damasio, 1998). Specific for this strain of research is the emphasis on bodily (somatic) components in explaining emotions and their functions. According to the Somatic Marker Hypothesis, somatic reactions and sensations are distributed in the periferal nervous system and given an important role in the process of learning, evaluation and decision making through their associations with external and internat events (e.g. Bechara et al., 1998; Loewenstein et al., 2001).

Contrary to Rolls, Damasio and his associates emphasize the lack of rational computations in the evaluative process (although he might agree on that they are “rational” in a bounded sense, see Gigenrenzer, 1999). Rather, they argue that emotional reactions (makers), produced by somatosensory feedback from the body (soma), to a given object or event guide the evaluative process. Alternatively, Damasio reasons, the peripheral body-loops can be substituted by, what he refers to as, “as-if body-loops”. The as-if-body-loops instantiate more directs route via representations of emotional states in the somatosensory cortex without involvement of the peripheral nervous system. In accordance with Roll’s view, Damasio agrees that the OFC is necessary in establishing a link between emotional states and factual knowledge. However, whereas Rolls claims that this connection is embodied within the OFC (which, with the help of the amygdala evaluates the emotional value of the situation), Damasio argues that the evaluation necessary includes a re-activation of earlier, associated, “emotional dispositions” (emotional memories). To Rolls, bodily states comprise noise in the evaluative process and the “as-if” loop just adds another idle route that does not make sense in a functional system.

Although the somatic marker hypothesis recently has received much critique on empirical grounds (e.g. Rolls, 1999; O’Caroll & Papps, 2003), it discusses the important advantages of distributing evaluative processes to extra-cerebral systems. This brings up the possibility that such markers, in a sense, also can be moved outside the body in a way analogous with the usage of tools as extensions of one’s limbs. Humans often know their social and physical environment well, sometimes better than their own bodies - a result of developing in close interaction with it over both phylogenetic and ontogenetic time. This could turn the environment into another medium for feedback. Although ultimately interpreted by the individual, emotional cues can be distributed in a way that facilitates the learning process. For example, by distributing the feedback of one’s emotional reactions, the bodily signals could potentially also become more

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[6] Yet another division is made between conscious and explicitly reported pleasure (liking) and objectively observed affective reactions (“liking”) (Berridge, 2000, 2003, see also section 9.1.3).

accessible to metacognitive strategizing. Targeted signal enhancement with technical devices has been argued to provide a promiesing avenue for the development of self-control strategies (for an overview, see Hall & Johansson, 2003).

3.1.3 Issues for Future Research

Are the discrete versus the continuous descriptions of emotion just different ways to conceptualize aspects of the same process or do they refer to orthogonal processes, one involved in the expression of affect (discrete emotions) and one in the learning and evaluation (continuous emotions)?

Knowledge about the way stimuli are ascribed values and subsequently evaluated is important for a better understanding of the role of emotions in the learning process. As illustrated here, even though advances by researchers, such as Rolls and Damasio have contributed substantially to this aim, there are still many heated controversies on fundamental issues. A lot more research is needed to specify how values are ascribed and evaluated. A special effort is needed to better understand how primary and secondary reinforcers interact in these processes.

As highlighted above, the empirical status of the somatic marker hypothesis is not clear. Recent attempts to manipulate peripheral autonomic nervous system have produced results that are both supporting (Bechara et al., 2001) and discouraging (O'Carroll & Papps, 2003) for the somatic marker hypothesis. Here, more research is warranted.

What role do peripheral, both somatic and extra-somatic, emotional cues play in the learning process? For example, consciously and unconsciously employed strategies that utilize emotional cues outside the body to learn are largely unknown.

3.2. Three Stages of Emotional Impact

As noted above, affective factors are essential for learning on different stages in the process. Emotions exerts their influence (i) indirectly by modifying the state of the cognitive machinery through selective attention (pre-encoding), (ii) by directly influencing the associations formed at the time of encoding and (iii) via a modulating impact on the way memories are consolidated over time (post-encoding). In addition, motivational factors make up the incentives to learn both simple associations and complex knowledge structures, as well as to explore the unknown (these issues will be discussed in sections 9 and onwards). The reader should be reminded of that the tri-part division outlined here, to a large extent, is artificial. The different stages of emotional influence all contain overlapping and interacting features in a natural environment.

3.2.1 Pre-Encoding Effects

Given an evolutionary perspective on the function of emotions, we can assume that environmental events of importance for the individual are especially susceptible to perceptual engagement. Studies also show that the emotional intensity, measured as arousal, of a stimuli or a situation increases the allocated attention (e.g. Armory et al., 2002). For example, the standard finding in a visual search task is that emotionally significant stimuli are detected faster than corresponding items with less emotional flavor. Hence an angry face among many happy faces is shown to be more readily detected than a happy looking face in a sea of angry counterparts (Öhman et al, 2001). However, as will be developed further in the section on Pavlovian conditioning (4), attention or explicit awareness is not a necessary condition for emotional stimuli to exercise influence on the individual.

Another, currently often used, experimental technique to show the influence of arousing stimuli on attention is the so-called attentional blink task. The attentional blink refers to the situation where detection of a target stimulus in a stream of other targets leads to an impaired detection, and subsequently remembrance, of the stimuli that follow immediately after the target. This effect is greatly diminished if the successive stimulus has an emotional flavor (see, for example, Andersson & Phelps, 2001), a phenomenon referred to as "inattentional blindness" (Dolan, 2002).

Naturally, the internal state of the subject also mediates learning. On a bigger time scale, self reported positive moods have been shown to facilitate both learning and creative problem solving (Isen et al., 1987). Similarly, positive emotions, in general, exert a beneficial influence on learning (Izard, 2003). However, these effects have been shown to be mediated by the similarity between the mood state at the time for learning and the time for retrieval – a phenomenon often referred to as state-dependent memory (e.g. Eich, 1992). A vast body of studies also suggests that people tend to attend more to information that is affectively congruent with their emotional state (Bower, 1994). Thus, happy people seem to attend more to pleasant stimuli, while sad people have an attentional preference to the opposite types of stimuli. As a result of increased attention, the respective information receives deeper processing, which result in better learning.

However, while much of the literature bases the study of motivational and emotional impact on learning on self-reports, using two-dimensional valence scales and physiological arousal measures, respectively, real life situations naturally contains motivational and emotional states imbued with complex cognitive content (Izard, 2002, Lazarus, 1991), each person with her own person-, or culture-specific idiosyncratic organization of previous knowledge (e.g. Nisbett & Masuda, 2003). This issue is addressed by investigators that include dimension, such as personality, cultural beliefs and self-esteem (self-competence or self-liking) in their learning studies. For example, it is argued that self-esteem produces an affective state that facilitates retrieval of information that are consistent with that state while hindering retrieval of traces that are inconsistent (e.g. Tafarodi, 2003). Another important caveat to the emotional effects on attention cited above is that they all (for obvious ethical reasons) include relatively weak emotional states that are limited in time. Another line of research that investigates the influence of punishment on learning concludes that strong negative emotions, induced by punishment, actually have a negative impact on learning through narrowing attention over a longer period of time (Lieberman, 2000).

3.2.2. The Encoding Phase.

Subsequent to the initial effect on attention, emotional states continuously contribute to the formation of associative links between various stimuli, contexts and responses. Since these processes will be the main concern in many of the later sections this discussion will be postponed until section 4 and onwards.

3.2.3 Post-Encoding Effects

The third stage of emotional influence relates to the post-encoding phase and, more specifically, how memories change over time - the way they consolidate. A situation that is accompanied with an emotional experience is better remembered than a neutral one (Cahil et al., 1996). This is true for both positive and negative experiences and, over a shorter time, most prominent regarding central details of the episode (Christianson & Loftus, 1991). However, a constant reconstruction of memories over time is a crucial factor in the poor accuracy in memory performance of even highly emotional episodes in the distant past (e.g. Loftus & Ketchan, 1994). While the gist might remain, details fade.

A recent study reasons that the amygdala serves a filtering function in order to preserve only the important features of emotional episodes (Adolph et al., 2001)[7]. An example of this phenomenon is the so-called flash bulb phenomenon, according to which strong emotions are argued to "light up" the content of the episode when affect is high (Brown & Kulik, 1977). Memories from collectively experienced tragedies, such as the M/S Estonia-disaster in 1994 and the events in New York City on September 11th , 2001, are examples of emotionally laden events that have been retroactively studied within this approach. However, as pointed out above, although emotionally significant experiences carry a better memory for certain details in the episode than do those that are emotionally insignificant, the reliability of such memories has proved to be far lower than was initially believed (see Schmolck et al., 2000). Interestingly, however, whereas accuracy decreases, the confidence in emotional memories often increases (e.g. Talarico & Rubin, 2003).

As was warranted earlier in this text, the relation between emotions and memories of specific stimuli and contexts over time needs more attention. For example, it has been suggested that the source of emotional arousal plays an important role in the subsequent consolidation process and thus the memoriability of certain events (e.g. Christianson, 1992; Libkuman et al., 1999).

3.2.4. Issues for Future Research

It is interesting to note that most experimental investigations of the emotional impact on attention, and information selection, use words as stimuli. Studies that include more naturalistic stimuli are rare with a few noteworthy exemptions, such as faces and stimuli with phobic relevance. More knowledge is needed to explore other categories of stimuli. In addition, more investigation is warranted into the effects that context has on attention.

There is evidence that global affective states, such as self-esteem and related concepts, have a considerable impact on learning. Here, a greater effort is needed to tie these constructs to either more basic emotional components or higher level goals, whose causal role in learning are better understood.

More studies are needed in order to capture the way the passage of time influence the memory of acquired knowledge depending on its source and content. There is a lack of investigation on how the origin of the information and its specific content influence how well it is remembered over time.

Most research on the post-encoding influences on learning and memory involves knowledge in a very limited sense. Experiments often include memory tests of word strings, visual aspects of a scene or links between episodes or behaviors. More seldom is the emotional impact on complexly organized knowledge, for example, beliefs or systems of beliefs, inquired.

Relating to the previous note, there is a very limited knowledge of social influences on newly acquired knowledge. There is a considerable literature available of the "on-line" social impact on decision making. Far less is known about the way social contexts affect already acquired knowledge.

Although there have been a considerable advance in the research on human emotion and learning, much of the hard work in the mapping of different learning mechanisms has been carried out on animals. As the knowledge of the non-verbal routes of learning in man increases, a better effort should be undertaken to

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[7] For a recent review of the role of amygdala in memory consolidation, see Hamann, 2001.

integrate these data with the rich body of findings from the animal literature.

4. PAVLOVIAN CONDITIONING

4. 1. The Prototypical Route to Learning?

Pavlovian conditioning (PC), or classical conditioning, as this basic form of learning also has been called, is probably the most investigated kind of learning. Since it provides the simplest instance of associative learning, it has been studied in organisms of different complexity. Moreover, it is relatively easy to study in experimental situations and is well suited for modeling and implementations of different kinds (e.g. in neural networks). Its applicability in well-controlled experimental conditions has also made its neural underpinnings more accessible than the ones underlying other forms of learning. Despite these advances, much knowledge is still missing. To take an often cited issue in the literature on the neural basis of Pavlovian fear conditioning: although it is established that the amygdala is crucial to fear conditioning, it still remains unclear whether this is the locus of learning and storage (LeDoux et al., 1999) or if it solely has a modulatory (enhancing) effect on learning that is distributed throughout the brain (McGaugh et al., 2002)[8].

Research on Pavlovian conditioning is introduced here not only because its mechanisms are relatively well known in comparison to other forms of learning, but because its functioning is of particular importance when we want to study the involvement of emotional variables in the learning process. Although its functions have been capitalized on in many applied settings, such as during cognitive and behavioral therapy (CBT), its role in other domains, among them education, is less obvious. However, by learning more about the involvement of emotion and motivation in this basic kind of learning, we provide a fundament to be used to increase the understanding of the functioning of other forms of learning – forms that are more readily integrated with educational practices.

In the traditional Pavlovian fear-conditioning paradigm, a neutral conditioned stimulus (CS+) that has been paired with a naturally aversive unconditional stimulus (UCS) elicits a greater conditioned response (CR) than a control stimulus that has not (CS). Subsequent repeated exposures to the CS+ without the presence of the UCS decreases the CR, which eventually converges with the response elicited to the CS-. This mechanism, referred to as extinction (Rescorla and Heth, 1975), is believed to create a new memory of the updated UCS-CS contingencies (Quirk, 2002)[9]. Successful Pavlovian fear conditioning in humans has utilized a variety of natural and artificially fabricated visual objects as CS, among them human faces (Esteves et al., 1994; Morris et al., 1998; Öhman 1986), animals (Seligman & Hager, 1972), line drawings of objects (Hamm et al., 2003) and geometric figures (Öhman et al., 1976; Phelps et al., 2001). Fear conditioning has been performed with UCS ranging from electric shocks (Lang, 1971) loud artificial noises (Hugdahl et al., 1977) and human screams (Hamm et al., 1989) and measured with different kinds of CR, such as the Skin Conductance Response (SCR) (Lang, 1978), cardiovascular activity (Reiff et al., 1999) and more recently, activations in the central nervous system (Morris et al., 1998, Critchley et al., 2002).

Through Pavlovian conditioning, an association is formed between the CS and the UCS, so that the presentation of the CS activates a representation of the UCS. In addition, the presentation of the CS might evoke a representation of the affective state that has become tagged to the stimulus. This embodies what is referred to as the emotional "tone", which is associated with a certain stimuli and which will be discussed in the later sections on aversive and appetitive learning. However, it is important to realize that these associations can also be established between a stimulus and a CR to form a simple stimulus-response connection, which by itself carries no information about the UCS.

Conditioning is seen as the way both humans and non-humans first learn about the causal structure of the world (LeDoux, 1996), but is seldom working in isolation from other learning mechanisms in a natural environment. Neither is it working in a similar fashion in all contexts and on all stimuli. The literature provides a vast number of experimental learning schedules (e.g. varying the temporal parameters of the CS-UCS pairings) that can be used in order to modify the subsequent learning effect (for a comprehensible overview, see Schmajuk, 1997). Below, I will highlight some recent findings on how PC can be modified by time and order, context, the kind of stimulus used, and awareness of the learner.

4.1.1. Time and Order.

There are several interesting ways that PC can be subdivided depending on the time that elapses between the CS and the UCS. For example, in delay conditioning, the CR is present throughout the presen-

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[8] Of course, the two views are not mutually exclusive as pointed out by LeDoux et al., 1999.

[9] Extinction has sometimes been conceptualized as a mechanism that eliminates what has been learned. However, this erroneous assumption has rested on the confusion of memory and performance. As pointed out above, extinction is nowadays considered to form new, rather than erase old, memories (Quirk, 2002). Because of its many potential applications in clinical psychology, extinction currently attracts much attention in both basic and applied research settings.

tation of the UCS, while in trace conditioning, the onset of the UCS follows the termination of the presentation of the CS. This distinction is interesting because the differential impact awareness is argued to have on the two. Delay conditioning is not dependent on awareness of the CS-UCS contingencies, while delay conditioning is (e.g. Manns, Clark & Squire, 2002 and Davis, 2002). Longer temporal gaps seem to need cognitive computations of another kind in order to form associations between the CS and the UCS - something that makes the acquired representations behave like episodic memories. In addition, the two forms of conditioning are dependent on partially different circuits in the brain (Davis et al., 2002; Squire, 2003). While delay conditioning draws on lower brain areas, such as cerebellum and the brain stem, trace conditioning is dependent on, first hippocampus and then, over time, neocortex. Despite of this known dependency on cognition, no studies have explored what kinds of minimal cognitive computations are necessary to produce trace conditioning. Also, most of the studies on these differences have used animals or human patients with brain lesions, which severely limits the generalizability of the results to learning in healthy individuals.

Another way cognitive variables are of importance is when the order of presentation is reversed for the US and the CS. For example, although the word "ice-cream" (CS) is presented after the hungry child has finished her appreciated meal (UCS), she will subsequently elicit a CR every time she is presented with the word, granted that she is hungry. However, a dog will not learn to associate a CS if its onset follows the offset of the UCS (e.g. Hall, 1996). Although it seems as if this kind of backward conditioning requires specific cognitive capacities, it is not clear whether it is just a question of failure in active maintenance of representations or an inability to pair the relevant stimuli (UCS and CS+). Different learning outcomes depending on the time elapsed between the CS and the UCS should also be visible in applied settings. However, the role of timing in, for example, an educational context is more relevant in regards to instrumental conditioning, or other forms of learning that are more dependent on cognitive elaborations. These will be considered in later sections.

4.1.2. Context.

Conditioned behavior is not only dependent on a fixed behavioral route elicited by a CS in a specific context. A specific conditioned response may not be the appropriate one at every occasion. Many factors have to be processed in order to determine which one out of several potentially conflicting routes of conditioned responses should be selected and which ones should be inhibited. For example, to answer the phone might be an automatized and highly functional behavior trigged by the sound of a ringing bell. However, the same behavior is less appropriate if one is exposed to the ring signal while being a dinner-guest in the home of an acquaintance. A major concern in recent research on learning and decision-making has been to flesh out the cognitive and neural processes underlying the managing of conflicts between different behavioral alternatives and the way actions are selected (Cohen, 2002).

A number of studies single out prefrontal cortex (PFC) and its connectivity with other parts of the brain as playing a decisive role in managing these processes (e.g. Cohen, 2002, Miller, 2003). Still, little is known about how this actually works. In addition, there are no answers to important questions, such as, How repeated behavioral patterns turn into simple rules (i.e. “if the bell rings, then answer the phone”), which in turn are conditional on other, more abstract rules (i.e. “this should only be done at home”)? As pointed out above, it is often believed that representations of various rules are initially represented in the connectivity between the PFC and other areas, such as the temporal lobes. As learning is automatized, the rules are relocated “down stream” to motor areas, such as the basal ganglia, which serves a crucial role in the initiation of behavioral sequences (Miller, 2003). This opens up for a greater flexibility because new rules can then be formed independently from earlier ones. Obviously, this also implies various problems if a particular context happens to activate a set of contradicting behavioral responses. In this respect, it is interesting to note (which is often forgotten) that the PFC is directly connected with most of the brain apart from primary sensory and motor areas, something that may give some insight to why rules of different kinds, activated by different input, can guide behavior in parallel.

4.1.3. Prepared Stimuli.

Seligman (e.g. 1971) has suggested that certain stimuli are prepared by biological evolution to enter into specific associations. Accordingly, there should be a structural component built into our cognitive apparatus that facilitates associations formed between certain classes of UCS and CS. Inspired by Seligman's suggestion, Öhman and his colleagues have carried out a range of empirical studies on stimuli that might have constituted a specific constrain on fear learning, so called “fear-relevant” stimuli (see Öhman, Flykt & Lundqvist, 2000, for an overview). Among the findings, angry faces, snakes and spiders have been observed to produce a greater CR that is more resistant to extinction than comparable neutral items when they are paired with an aversive UCS. The magnitude of the conditioned response also seems to be dependent on factors, such as the directedness of the CS. For example, the direction of the gaze of facial conditioned stimuli seems to be an important factor in fear-conditioning paradigms (Dimberg et al., 2000). This phenomenon is not only present in aversive conditioning. A recent imaging study, in which participants watched unfamiliar faces, shows that activation in parts of the brain that are strongly involved in reward learning, such as dopaminergic regions, vary as a function of gaze direction of the displayed faces.

Today and over the course of evolution, the human face has been (and is) crucial to quickly attend to, interpret and predict. In accordance with the results cited above, and other similar findings, faces are thus argued to have exerted a specific influence on the design of the learning system (Adolph, 1999, 2002; Öhman, 1986) (see also section 6.1). It is interesting to note that both clinical studies and results from imaging of healthy subjects indicate that the amygdala is most sensitive to fearful faces (Adolphs, 2001; Wahlen, 1998; Davis & Wahlen, 2001). Whalen explains these findings by suggesting that a fearful face signals a present, but not localized, danger, something that is more threatening than a well localized source of danger, such as an angry face (Whalen, 2000).

Although most reports of prepared stimuli have focused on evolutionarily relevant objects, also man-made objects that have become "prepared" in a cultural setting produce similar results. For example, a gun pointed at the subject and paired with a loud noise produce a CR effect of a magnitude similar to a snake conditioned to a mild electric shock (Hygge & Hugdhal, 1976). In comparison, the gun pointed to the side did not constitute an equally effective CS. It is reasonable to assume that this effect is a result of the greater over all arousal induced by the authentic combination of a gun and a burst of noise, especially when the direction of gun is threatening. No studies have followed up this line of research by increasing the ecological validity of the UCS in pairings with either biologically or culturally prepared CS. In general, more research is needed in order to delineate the degree of evolutionary and cultural preparedness of different stimuli combinations.

4.1.4. Awareness of the Conditioned Stimuli.

Not only do biologically fear relevant stimuli that are aversively conditioned show a resistance to extinction, they also produce a CR to conditioned stimuli even when the CS are presented subliminally and thus not accessible to conscious awareness (e.g. Morris et al., 1998; Öhman & Soares, 1993). This effect is not observed with fear irrelevant stimuli. However, in spite of some affirmative indications (Flykt, 1999, cited in Öhman & Mineka, 2001), it is still an open question to what extent subliminally presented stimuli, which have acquired their fear-relevance through cultural learning, such as pointed guns, are enough potent to evoke the same response.

These findings of fear-responses to stimuli presented outside conscious awareness have been taken as supportive of the idea of an implicit fear learning system that is partially encapsulated from cognitive influence (e.g. Öhman & Mineka, 2001). Along the same lines, Johnsrude, Hamm and Vaitl (1996) found that, using the potentiation of the startle reflex as a measure of aversive conditioning, there was no relationship between awareness of the learned UCS-CS contingency and the conditioned response. Instead conditioning occurred with the same frequency among people regardless if they managed to report the contingency or not, which shows that contingency awareness, as indicated by a verbal report, did no mediate the emotional response. Still the study does not tell us anything of what the result would look like would the experimentators use another behavioral indicator, such as choice, as a factor.

Although there is considerable amount of behavioral and neural data suggesting the partial independence of conditioned responses and conscious awareness, some investigators still claim that emotional learning is dependent on explicit awareness of stimulus contingencies (Dawson, 1971; Lovibond, 1991; Lovibond & Shanks, 2002, Lovibond, 2003).

4.1.5. Issues for Future Research

More experimentation is needed on healthy humans on trace versus delay conditioning and backward conditioning. This may reveal more about the extent cognitive variables are present in conditioning.

How are complex/abstract rules converted into simple conditioned responses and how does this conversion differ between rules of greater and lesser emotional relevance, such as altruistic actions and answering the phone, respectively?

There is also a need of a greater specificity of the role played by the interaction between the PFC and brain regions that are important in the emotional evaluation of events and stimuli, such as the OFC and the temporal lobes (including amygdala).

As pointed out by Öhman and Mineka (2001), there are no data on amygdala specific processing of biologically fear-relevant stimuli, something that would inform both evolutionary theorizing and cognitive neuroscience.

Issues regarding perceived beauty and gaze direction are issues that have a potential bearing on more practical settings. More research is needed to examine to what extent, for example, an attractive face could serve as a potent CS, or even an UCS, in certain situations.

More research has to be conducted on the dimensions of stimuli that may be prepared (by culture or biological evolution) to engage in associations with aversive and rewarding UCS. For example, although there is a huge body of research on what social dimensions are rated as approachable and desirable, very few reports on how these are engaged in the learning process. In addition, whereas the sex and age of facial conditioned stimuli is shown to mediate aversive learning, no studies have investigated the impact of other, equally important, categories, such as ethnic and racial belonging.

There is still work to be done to settle precisely what aspects of learning are dependent on conscious awareness, although this may presuppose the unlikely event of an agreement on the meaning of “awareness” (see Holender, 1989 for a critical review).

To date, researchers have only investigated the role of awareness in Pavlovian conditioning. Research involving other forms of learning could illuminate both the notion of awareness and the underlying components of different types of learning, such as observational and instructed learning, and imitation (see also sections 6-6.3.).

5. IMPLICIT AND EXPLICIT LEARNING

Both our private intuitions and a long tradition of research suggest that learning is not all about consciously binding stimuli, events and experiences together. A discussion that ranges over many sub-fields of psychological research today is related to the separation of an implicit and an explicit system for learning – a distinction that owes much of its clarity to Squire and colleagues (see e.g. Squire, 1992). Whereas the implicit system is responsible for unconscious and/or non-verbal processes, the explicit system manages the conscious/verbal aspects of the learning process.

The way emotion operates in the learning process is often implicit (Pankskepp, 1999; LeDoux, 1996). Feelings are not per se symbolically represented and the way emotional states determine the weights of the formed associations between stimuli or responses lacks direct correspondence in natural language. However, emotions can equally well be symbolically represented and thus manipulated directly within the exlicit system.

Since the infleuncial paper by Zajonc in 1980, "Preferences Needs No Inferences", the emotional influences on our cognitions outside explicit awareness has captured a growing interest from both psychologists and, more recently, neuroscientists that studies learning in humans. Supported by a long anecdotal tradition from the clinical field, the findings by Zajonc marked a new era of investigation in the dissociations between emotion and cognition. Since then, a vast body of findings points to emotions as primary to, and independent of, cognitions (Zajonc, 2001; LeDoux, 1996). Moreover, to the alarm of old-school cognitivists, the emotional part turned out to be the dominant in many tasks that traditionally had been consieved as purely cognitive, such as decision making (see e.g. Bechara et al., 1998 and Loewenstein & Elke, 2001). While the cognitive system is seen as dependent on the emotional, the reverse relationship does not apply (Balkenius, 1995).

Although the division between implicit and explicit processes often sparks controversy, as pointed out above, several lines of research have supported the division. One such line, focuses on two neural regions in the temporal lobes that are differentially implicated in the two proposed systems: amygdala in the implicit or non-declarative system and hippocampus in the explicit or declarative system. Before some of the recent research on these components with relevance for our discussion on emotion is reviewed, it should be remembered that these systems, under normal circumstances, work in concert.

5.1. Explicit Learning of Emotions and the Hippocampus

Starting with the explicit system, Howard Eichenbaum (2001) has advanced an argument of hippocampus as an essential part of the neural learning mechanism that is involved in the shaping of explicit episodic memories of emotional experiences in humans, and their non-verbal (spatial) counterparts in other animals. Research on episodic memories and the hippocampus has received an immense attention lately, both in neuro-psychology, cognitive neuroscience and in the comparative psychology community (Tulving, 2002).

According to Eichenbaum (e.g. 2002), hippocampus is critically involved when new experiences and their relation to one another are encoded. It is responsible for building up of a network - a memory space - of information, which due to its interconnectivity through common elements, comprises an organization of knowledge that supports flexible inferences. However, according to this model, no inferences are going on within Hippocampus itself. Instead, the involvement of another "smarter" system is crucial. The appropriate candidate for this job, according to Eichenbaum, is the frontal lobes. The dense neural connectivity between the hippocampus and the neocortex in the frontal lobes is therefore of crucial importance in the expression of both declarative memories and in the reconstruction of particular experiences (episodic memory). Using a somewhat provocative metaphor, Eichenbaum describes the relationship as "Hippocampus holds up the network on which the frontal lobes surfs" (2002). However, there is still a lack of understanding of the role played by parts of the brain that are responsible for emotional processes (e.g. amygdala) interact in this process (see, for example, Maratos et al., 2001), although some progress might be in sight because the development of new contextual conditioning paradigms in animals.

Many researchers argue that the role of Hippocampus in memory formation is limited in time. Lesion studies in rats and monkeys, as well as clinical studies in humans, show that this region is especially critical in the first time following learning. This is shown, among other ways, through the severe deficits in recent, but not remotely acquired, memories following lesions of the Hippocampus (Eichenbaum, 2001). The relation between hippocampus and different cortical areas that are assumed to retain memories over a longer time period are still not well known. A recent debate in the field of memory consolidation research has been whether there exists a number of discrete stages during which the learned information is transferred through different functional regions or a constant involvement of them all (Eichenbaum, 2001). For example, Haith et al. (2001) argue that memories are transferred from the hippocampus, through the entorhinal cortex, to a more permanently solidified location in the neocortex (e.g. Haith et al., 2001), while Nadel and colleges (1997) propose that the involvement of the hippocampus is selective for episodic and spatial memory. Moreover, they argue that these memories always involve active connections between hippocampal and neocortical areas – a stance that reinforces the importance of a distributed neural network model of memory.

As new imaging techniques have developed, the interest in memory consolidation has increased. Because we can image the areas involved in the different temporal stages of the consolidation process, we can learn more about the specifics of memory, such as why certain features become more prominent over time, why their inter-connectedness and over-all organization changes and why we loose other features along the way. The influence of emotion and motivation can hardly be overestimated in this process (for a comprehensible review of consolidation research, see McGaugh, 2000).

5.2. Implicit Emotional Learning and the Amygdala

While the declarative memory system, including the hippocampus, is related to memories of emotions, another system that is centered around amygdala, subserves emotional memories, such as conditioning. Lesions on Hippocampus seem to have no effect on conditioning (LeDoux, 1996, 2000). However, if amygdala is damaged, the emotional significance of stimuli previously established by association with a punishment or reward is lost (LeDoux, 1996) together with the capacity to form new such associations (Aggleton, 1992).

In primates, the amygdalaoid nuclei receive input from, and projects to, several parts of the prefrontal cortex, such as the orbitofrontal cortex (see also section 3.1.2.). It is also linked to other subcortical structures of the brain, among them the basal ganglia, which is involved in the initiation of action. LeDoux and his colleagues have pointed out that amygdala also receives direct input from visual and auditory channels that bypass primary sensory corticies (that are needed for object recognition). For example, a visual pathway via the thalamus is argued to provide a "quick and dirty" information route to the amygdala, providing crude visual information that is enough to initiate an emotional response before it is processed by cortex (LeDoux, 1996). This route is argued to be a functional circuit through which information can be processed without explicit awareness.

Although both Rolls and LeDoux agree on the distinction between an implicit (non-verbal) and an explicit (verbal) route for the evaluation of rewarding and aversive stimuli and the corresponding learning mechanisms, their views differs on the extent to which they grant the amygdala information processing capacity of object like properties. LeDoux is generous, while Rolls prefer to distribute the computations to other areas. Among other things, Rolls argues that stimuli in the environment always are processed on an object level (by the cortex) before amygdala and the rest of the implicit system evaluates their emotional significance (Rolls, 1999). Once the information is processed on an object level, the orbitofrontal cortex, with the help of amygdala is evaluating its emotional value, followed by an appropriate response. A number of studies do indicate that amygdala activity is involved in the processing of emotionally significant stimuli that are presented both with and without the subject's explicit awareness of the CS (e.g. Morris et al., 1998). However, the poor temporal resolution of images acquired with fMRI does not allow us to specify the order in which cortical and amygdalaoid structures are activated[10].

5.3. Issues for Future Research

Although our knowledge of the function of hippocampus has increased, many of its functions remain veiled in ignorance. So far, its role has focused on explicit learning and less interest has been invested in its working in implicit learning tasks.

Research is also needed to further explore the hippocampal role in acquiring knowledge that is unique to humans (e.g. language) and the way this is analogous to the spatial learning in other species.

Another burning issue for many research groups with access to functional brain imaging techniques is to explore the functional connectivity between hippocampus and other areas, most prominently the frontal lobes and the amygdala.

The vast majority of studies on implicit emotional learning have used aversive conditioning paradigm. More knowledge is needed of the behavioral, cogni-

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[10] There is currently many ways in which researchers tries to advance the poor temporal resolution in fMRI. One is to build more powerful machines, another is to construct experimental designs and data-analyzing tools that allows existing machines to produce better specificity. For a good introduction to, so called, rapid event-related, fMRI, see Rosen et a., 1998).

tive and neural correlates involved in implicit learning involving reward.

A greater effort is needed in order to better understand how cognitive strategies modifies and build on basic learning mechanisms and automatic (non-verbalized) processes in order to achieve vaious goals.

It is not clear how models of stimuli evaluation, for example Roll's theory on "common currency" as outlined above, relate to the proposed gap between different explicit and explicit learning.

6. SOCIAL LEARNING

6.1. The Common Route to Learning?

As mentioned above, the biggest share of the knowledge that humans acquire about the affective nature of various stimuli or events may be transferred via more indirect routes of learning than Pavlovian conditioning (Rachman, 1977). The evolutionary significance of social means of learning information is emphasized by the fact that most vertebrates share this capacity (Krebs & Davies, 1994). However, although humans share many of the emotional aspects of learning with other animals (Macintosh, 1983), the way objects, events and the causal structure that binds them is represented, is certainly very different across species. This difference should also apply to the associative processes underlying different kinds of learning (Small, 2002). While Pavlovian conditioning involves direct experience with the CS and the UCS (Rescorla, 1988), in observational or vicarious learning (Hygge and Öhman, 1978, Mineka & Cook, 1993, Miller & Dollard, 1941; Bandura, 1977) knowledge of the same causal contingency is acquired by observing other individual's emotional expressions to an object or event. This way of transferring information via social cues is shared by primates (Mineka & Cook, 1993; Heyes, 2001) and, according to some studies, birds (e.g. Biederman, 1986) and mice (Kavaliers et al., 2001).

Knowledge that is acquired via symbolic representations, such as language, is arguably unique to humans, with some limited exceptions (see e.g. Savage-Rumbaugh et al, 1985) and often known as instructed learning (Grillon et al., 1996; Hugdahl & Öhman, 1977; Phelps et al., 2001). Imitation is another phenomenon, or rather a conglomerate of phenomena that often occurs in conjunction with learning. The interest in social learning and its emotional components is not only shared by psychologists, neuroscientists and educational scientists. Recently, also economists have entered the stage (e.g. Schotter, 2003).

Below, I will discuss several kinds of social routes to learning. Similarly to the section on Pavlovian conditioning, I am emphasizing findings on the basic process of attaching emotional valence to stimuli and events, although also some research addressing the broader question of how social means are used to reinforce behavior are mentioned. The influence of reward and motivational state on learning is discussed in section 8 and onwards.

6.2. Learning through Observation

In observational learning protocols, most studies on human and non-human primates have employed behavioral measures to test the acquired learning. Often, the interest has targeted either imitation (e.g. Meltzoff, 1977; Heyes, 2001, for a review, see Meltzof & Decety, 2003) (see also 6.4) or complex operant behaviors in attempt to achieve a specified goal (e.g. Bandura, 1977; Cadwell & Whiten, 2002). More recently, a growing body of research has addressed questions about direct links between sensory and motor representations, so called "mirror neurons", in the brain with relevance to imitation (Rizzolatti et al., 1999; Wohlschlager & Bekkering, 2002). Along a similar line of research, new findings describe partially overlapping neural representations of own emotional experiences and the perception of emotional expressions in both human and non-human primates (e.g. Carr et al., 2003). These data resonate well with studies that demonstrate a positive correlation between peoples own level of arousal and the level of observed arousal in others (Levenson & Reuf, 1992, for a comprehensive review, see Preston & deWaal, 2002).

However, a far less investigated topic is the role of representations of other's emotional expressions as UCS in learning during observation. In a study on food aversion in humans, an evaluative learning effect was found after flavored drinks had been systematically paired with a confederate's facial expression of dislike (e.g. Baeyens et al., 1996). Interestingly, the same study also demonstrated that the acquired emotional responses were independent of explicit knowledge of the CS-UCS (i.e. drinks - model's emotional expression) pairings, supporting the explicit/implicit distinction outlined earlier.

In an early study on observational fear learning in humans, Hygge and Öhman (1978) exposed subjects to a confederate's fear reactions to either fear-relevant (e.g. snakes) or fear-irrelevant stimuli (e.g. flowers). Subsequent presentations of the CS showed that subjects acquired a more persistent CR (SCR) to the stimuli paired with the fear expression in general and to the fear-relevant stimuli in particular. During the following decade, Mineka and her collaborators (e.g. Mineka et al., 1984; Mineka & Cook, 1993) carried out a series of studies on vicarious fear conditioning in monkeys. In the typical experiment, they exposed laboratory-reared rhesus monkeys to wild-reared monkey's natural fear-reactions to fear-relevant (e.g. toy and real snakes) and to neutral (e.g. wood blocks and flowers) objects. Fear learning in the observers was then estimated immediately and after different follow-up periods with the help of a number of behavioral measures of distress. In general, there was a high correlation between the observer's level of disturbance at subsequent tests and the disturbance behavior of the model during conditioning. More importantly though, during post-conditioning exposures to the CS+, the observer's behavior was highly related to both own and the model's fear-reactions during the learning phase, which reinforces the assumption that a perceived emotional reaction can itself serve as a powerful UCS. In summary, the studies by Mineka and colleagues suggest a rapid, strong and persistent learning effect following exposure to another monkey's fearful reactions, something that appears to be especially salient when the real (or attributed) source of the reaction is a fear-relevant stimulus. Based on these findings, Mineka and Cook (1993) reasoned that the mechanisms involved in vicarious fear learning are similar, if not identical, to those underlying Pavlovian conditioning.

A recent study that uses a learning protocol similar to the one utilized by Mineka et al., shows strong and persistent fear learning in toddlers after they observed their mothers fearful expressions to fear-relevant objects (Gerull & Rapee, 2002). The strong impact of observational fear learning is further supported in a recent experiment on adults by Olsson and Phelps (2003). In this study, participants learned to expect a mild shock to the presentation of a specific angry face, either through direct experiences (Pavlovian conditioning), or indirectly, via observation of a confederate's emotional expressions to the designated face or through verbal instructions given by the experimenter. When tested, all groups showed similar levels of learning to fully visible (supraliminally presented) faces. Replicating earlier studies (e.g. Esteves et al., 1994, see also section 4.1.4.), the Pavolovian group also displayed a significant learning response to unseen (subliminally presented) stimuli. Interestingly, this was also the case in the observational group. However, this learning response to masked stimuli was absent in the instructed learning group (see also section 6.2). This suggests that representations of valence, acquired solely through symbolic communication, have a differentially impact on learning responses compared to representations acquired through own emotional experiences or through the perception of other's emotional expressions. These results stress the importance to take the way learning occurs, as well as attentional factors, into account when we discuss learning. It also provides additional support to the previously proposed distinction between explicit and implicit learning mechanisms.

6.3. Learning from Instruction

The stubborn focus on traditional conditioning as a means of learning has left many questions unanswered in regards to the sources of learning that may dominate in our natural environment – an environment that to a large extent is social and linguistic. Similar to research on observational learning, the work on instructed learning is dominated by aversive learning paradigms. Incentive learning through verbal communication is a topic that is discussed more in sections 8, 9 and10.

In addition to observation, language is an indirect way of acquiring knowledge of the emotionally relevant qualities of stimuli and events. Both clinical accounts, which retrospectively targets the etiology of phobic fears to fear-relevant stimuli (King, Gullone, & Ollendick, 1998) and experimental studies, involving stimuli that acquire fear provoking qualities through storytelling (Field et al., 2003), reveal that verbal instructions comprises a potent means to fear learning. In addition, subjects that have been verbally instructed to expect a shock paired with the presentation of a specific CS (instructed learning) and then later exposed to fully visible CS also display a similar SCR-pattern as the one demonstrated following Pavlovian fear conditioning in humans (Hugdahl & Öhman, 1977; Grillon, et al., 1991; Phelps et al., 2001; Funyama et al., 2001). For example, Hugdahl & Öhman (1977) conditioned subjects to fear relevant versus fear irrelevant stimuli either through classical conditioning or instructions. In one part of the experiment, subjects who were classically conditioned, later received instructions that no more shocks were going to be presented (extinction). The results showed that instructions symmetrically influenced both acquisition (enhanced) and extinction (decreased) of responses (SCR) to fear-irrelevant stimuli. However, while it facilitated potentiation to fear-relevant stimuli, it failed to extinguish the CR to the fear-relevant CS+. Instructions were shown to be equally effective in producing a CR as traditional conditioning. The dissociation between cognitions and automatic responses in the extinction part was taken as supportive of the idea that learning on different levels is partially independent from each other. This argument, partially drawing on earlier descriptions of two components of classical conditioning: one emotional and one cognitive (Mandel & Bridger, 1973), has been further elaborated by Öhman & Mineka (2001). They suggest a two-level of learning approach to fear conditioning according to which the explicit knowledge of the CS-UCS contingencies is represented separately from its implicit components. Following this, they argue, explicit expectancies cannot fully account for conditioning. There are several similarities between these two proposed levels and the previous discussion of an explicit system dependent on the hippocampal complex and an implicit system depending on the amygdala.

A recent study by Phelps et al. (2001) used both functional magnetic resonance imaging (fMRI) and SCR measures to examine learning in an instructed fear paradigm. Similarly to the study by Hugdahl and Öhman, their results highlight both similarities and differences between anticipatory responses following verbal learning in the absence of direct experience and classical conditioning. For example, while both kinds of learned responses involve fear-responses (SCR) that was related to activity in the amygdala, Phelps and her colleagues reported that following instructed learning, this correlation was mainly carried by the left hemisphere (see also Funayama et al., 2001). Among the possible explanations for this laterality effect, the authors point out known hemispheric difference in processing of visual and verbal information.

Despite that observational and instructed learning may be the most common route of learning about emotional qualities in our surrounding, few systematic comparisons are made between these two indirect forms of learning and Pavlovian conditioning. As previously noted, a recent study (Olsson & Phelps, 2003) demonstrates a difference in learning response following instructed learning on one hand and Pavlovian and observational learning on the other. These data reiterate earlier findings of similarities between learning acquired through own experiences and the perception of somebody else's reactions to the same events. They also speak to the difference between emotional learning through these two means versus the indirect route through symbolic communication. Different kinds of learning might appear to have different effects depending on whether its impact is probed by implicit or explicit measures. Many of the studies discussed above report arousal responses estimated by the skin conductance or patterns of brain responses – both implicit in nature. Verbal instructions might contain information that is better utilized on an explicit level. Relating to this, it is important to further explore the behavioral (especially in ecologically valid settings) effects of these different types of learning beyond physiological markers.

Lately, behavioral economists (e.g. Schotter, 2003) conducting, so called, intergenerational games experiments, have noticed that participants prefer to receive (and use) verbal instructions to the opportunity of observational learning in order to trying to maximize their own economic gain. Moreover, participants choose to decide in accordance with the given advice even when it is contrary to their own beliefs about the most advantageous decision. It also turns out that following the advice, in general, is rational, because it results in an economic outcome closer to a "good" equilibrium than alternative ways of learning. These experiments try to simulate cultural learning, most notably the one taking place over generations, between parents and their offspring. However, as is the case in much of the work in experimental economics, emotional and motivational factors are scarcely, if at all, investigated. Although improvements are needed, this type of experiment provides a stimulating illustration of how semi-ecological aspects of cultural learning can be modeled.

6.4. Learning by Imitation

By providing an effective route of transferring important information to conspecifics, social signals have provided a crucial learning tool for many species (Hauser, 1996). Still, only primates and birds show signs of imitation (Heyes, 2001). In a recent experimental illustration of the similarities between imitation through observational learning and operant conditioning, an ape first observes and subsequently imitates a fellow primate in her attempts to manipulate and open artificial 'fruits' designed as analogues of wild foods (Williams et al., 2001). Based on findings from research on mirror neurons in monkeys (e.g. Rizolatti et al., 1999), the authors reason that the neural mechanisms involved in these processes are partly the same as the ones that would be activated if the ape successfully learned the trick on her own (i.e. by an operant trial and error procedure). However, this does not take into account possible differences between imitation and emulation. While learning through imitation refers to the copying by an observer of a feature of the body movement, emulation learning means that the observer learns via observing the environmental relationships involved in a task, but not the motor behavior used (Tomasello et al., 1993).

Much of the literature produced on imitation does not spend much effort on its rewarding properties. Also, while most studies on learning through imitation in humans have included explicit teaching and demonstration, fewer studies have looked at implicit imitation where no explicit demands are present. Interestingly, implicit reward processing has received increased attention from researchers in many fields outside psychology, for example by computational modelers (e.g. Price & Boutilier, in press). On a behavioral level, the unconscious influence of social goals (e.g. liking) on mimicking of other's behaviors has caught the interest of many social psychologists. In a series experiment, Bargh and his colleagues have recently found that social motives can have a strong effect on unconscious imitation (e.g. Chartrand & Bargh, 1999). Although these experiments demonstrate the implicit influence on behavior, it targets relatively simple actions and gestures. More interesting for applied purposes is when imitation is studied in association with other variables, such as permanent or stable characteristics in the learner and the model (see sections 6.4., 9 and 10).

As the studies cited above shows, imitation can occur on different levels of complexity and it can be supported by a varying degree of conscious or explicit effort by the imitator and her model. Byrne and Russon (1998) outline an interesting hierarchical approach to imitation in order to understand the relationship between its components at a low action level and higher "programmatic" levels in the cognitive hierarchy. Still, how these different levels are affected by emotional and motivational variables are not known (see section 9 for a more on the impact on reward on different levels of cognitive functioning). Another important topic in the study of learning through observation, whether or not it includes imitation, is the influence of model- and observer-specific characteristics on learning. This is discussed next.

6.5. The Role of the Model/Instructor

Not surprisingly, the specifics of the model are of great importance in social learning situations. Some theorists have stressed the importance of inter-species similarity between the model and the learner (e.g. Tomasello, 1993)[11]. There are also empirical findings of that intra-species similarity is an important factor in learning through imitation. For example, in humans, perceived similarity in a model is argued to facilitate imitation of aggressive behavior (e.g. Dove & McReynolds, 1972). In toddlers, it has been shown that mothers are significantly better models in teaching their children about the aversive qualities of novel stimuli through facial expressions, than is a comparable, unrelated, woman.

Studies on more complex learning report that both the age of, and the degree of identification with, the model/instructor, matter. While similarity is advantageous in transferring social skills (Schunk, 1987), dissimilarity favor the transfer of skills taught in school, such as writing skills (Schunk, 1991). Along these lines, weak learners are shown to learn more by observing other weak models, while better learners learn more from good models (Braaksma et al, 2002).

6.6. Issues for Future Research

Whereas there has been a surge in research on the behavioral and neural similarities of own emotional experiences and the perception of emotional responses in others, there is very little literature available on the influence of these "mirroring" processes in human learning.

The currently available data on the acquisition of emotionally relevant information through observation and instruction concern aversive learning. Observational and instructed reward learning is a promising field for future investigation.

Several questions concerning differences/similarities from Pavlovian conditioning (and observational learning) remain. Studies that systematically compare instructed learning with other forms of learning are important to advance our understanding about the different processes and representations involved in various kinds of learning.

There is an apparent lack of research on model-relevant factors in both human aversive, appetitive, and more complex forms of learning. For example, in what way is similarity between the model/instructor and the subject affecting the learning process? To what degree is this process mediated by intra-individual factors, such as attention and personality or inter-individual aspects (e.g. trust and liking)?

Although research in other fields (decision-making) show that it matters to people's behavior whether behavior-relevant information is made public or kept private, there is virtually no studies on how social learning is affected by the knowledge of that the information is shared among many, or kept to a minimum (e.g. illustrated by teaching in large versus small groups).

The long-term learning effects of different routes of indirect (social) emotional learning are unknown. Studies that range over a greater time-span are needed.

7. EVALUATIVE CONDITIONING

Research on human emotional learning inspired by learning in animal has often been limited to the study of associations between emotional markers and relatively simple stimuli or context. Another tradition of investigation on emotional learning, which mainly engaged social psychologists, has focused on the cognitive and meaning based aspects of learned associations in humans. Evaluative conditioning (EC) illustrates an active research paradigm within this tradition. EC combines emotional evaluations and higher order cognitive constructs.

Evaluative conditioning (EC) has been describes as the changes in "liking of a stimulus that result from pairing that stimulus with other positive or negative stimuli" (De Houwer et al., 2001, p. 853). A classical example of EC is the so-called luncheon technique. This protocol describes how a particular political slogan combined with a free lunch enhanced the liking of the slogan compared to control stimuli (Razan, 1954). Another illustrative example is the way a nonsense syllables acquire the same valence as the positively or negatively valued words that they are paired with (e.g. De Houwer et al., 2001).

Subsequently, EC has been shown most frequently in the visual domain with picture-picture and picture-word stimuli, in the haptic and in the gustatory domain (for a list of examples, see Deouwer et al., 2001). Relating to the gustatory domain, it is noted that negatively valenced UCS produces far more reliable results than positive comparisons (Rozin et al.,1998). The possible onto- and phylogenetic causes

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[11] Of course, this does not exclude that targeted selection-forces could have sculptured specific patterns of inter-species understanding, for example the one between dog and man (Brown et al., 2002).

of this asymmetry deserve more attention. Interestingly, also several instances of cross-modal conditioning have been observed. For example, Todrank et al. (1995) randomly assigned images of human faces to a variety of odors, which were previously rated as more or less likeable. The subsequent evaluation of the faces showed a change towards the value of the UCS (the odor). However, the authors report that this only happened when the odors mimicked smells that could plausibly be associated with humans (i.e. smells similar to sweat and perfume) – a phenomenon similar to social or biological "preparedness" as outlined in section 4.1.3. The pairing of specific odors, as well as pheromones[12] with images of humans, varying sex, age and attractiveness, could further illuminate the mediation of social factors in EC. As with gustatory stimuli, visual UCS with a strong negative content tend to show more reliable results of EC than those with a comparatively positive content (De Houwer et al., 2001), although some interesting differences are seen. For example, when potent negative images were used as UCS no change in evaluation was observed with olfactory CS (Rozin et al., 1998).

The similarities between EC and Pavlovian conditioning (PC) seem obvious. However, a recent review on 25 years of EC research concludes that there are several interesting differences that deserve more attention. For example, in EC, unlike in PC, both forward (CS precedes UCS) and backward conditioning (UCS is presented prior to the CS) are observed. Moreover, EC appear to be more resistant to extinction than those formed via PC (see, for example, Baeyens et al., 1995). How these phenomena can be explained by differences in the stimuli employed (e.g. while PC often uses biologically relevant stimuli as UCS, EC commonly employ second order UCS) remains to be explored.

7.1. Demand Effects and Implicit Measures

Demand effects and interference by metacognitive strategies have often been singled out as the source of weak and unreliable experimental effects in EC (Deuower, 2001; Hammerl & Grabitz, 2000; Purkis & Lipp, 2001). Because this has been a heated topic of debate, some of the measures that have been taken in order to bypass these obstacles, will be discussed below. Many of them capitalize, in one way or another on, what traditionally has been called implicit measures, indirect ways of estimating performance designed to bypass conscious awareness and thus the influence from metacognitive strategies (see also sections 5-5.3.). The use of implicit methods has progressively increased in both psychology and in neuroscience over the last decade.

One way evaluative measures can be made less obtrusive is to base them on task performance that is not related to the measure of interest, i.e. the subject is asked to perform a task that is irrelevant for the experimental hypothesis. For example, reaction time in category sorting tasks has been utilized to capture the variance of likeability of different social categories – an evaluation that often conforms to demand effects (e.g. political correctness) when estimated through self reported (i.e. explicit means) (Greenwald et al, 2002; for a critical overview of this approach, see Fazio & Olson 2003). As discussed earlier, other ways of probing implicit processes includes subliminal presentation of stimuli. If a subliminal prime of either a positive or negative stimulus precedes the target stimulus, the response time has been shown to be dependent on the congruence of the prime and the target, so that emotionally congruent stimuli leads to shorter reaction times than to incongruent items than incongruent stimuli (De Houwer et al, 2001). A recent study by Berridge et al., presents a similar effect where a subliminally presented positive prime (a happy face) causes thirsty people to drink more fruit juice (and give higher ratings of the quality of the fruit juice) than after a neutral prime. This and other similar findings, stresses the importance for people to make sense of their experienced feelings, something that often results in misattributions which, in turn, affect behavior. Note that it is not clear whether the increased drinking behavior resulted directly from the prime or from the subsequent attribution.

Other implicit markers are small and transient facial reactions, so called "micro expressions" (Ekman, 1999), often sampled with an electromyograph (EMG), and argued to "mirror" the valance of confronted stimuli (e.g. Dimberg et al., 2001). For certain positive affects, researchers (e.g. Berridge) have been using more sustainable expressions that are observable across species. Moreover, Cacioppo and colleagues have successfully employed event-related brain potentials as an on-line measure of the evaluation of emotionally significant stimuli (Cacioppo et al., 2000). In addition, it can be argued that imaging techniques is another category of helpful implicit measures.

In search of measures with greater face validity, some psychologists with an interest in social liking have sampled whole sets of molar behaviors towards others. To take one noteworthy example, Dovidio et al. (2002) developed a technique to analyze video recordings made of white subjects that interacted with Black (and White controls) confederates. The recordings were subsequently rated separately for verbal and non-verbal information by different judges. The results showed that the subject's explicitly reported attitudes of Blacks were only correlated with the friendliness as measured by judge's ratings of their verbal interaction. Interestingly, the implicit measure of attitudes towards Blacks (reaction times measure in

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[12] For a study on learning and phermones in rats, see Moncho-Bogani, 2002).

a category-sorting task) did significantly predict their non-verbal, but not their verbal, friendliness.

Although these findings provide some additional credibility to the presented reaction-time measure, its underlying features lack clarity as do the purported link to, for example, affective evaluations[13]. Moreover, the question remains concerning the relation between implicit and explicit attitudes in social evaluations. Available models try to explain which attitude (explicit or implicit) becomes the dominant based on a mapping of the connection between situational variables, such as motivation, and the "opportunity to deliberate" (see Fazio & Olson, 2003). Unfortunately, these accounts suffer from the tendency to explain through definitions in order to save their explanatory value. However, before one spend the effort on explaining how the two relate to each other, much work is required on exploring their separate nature through finding estimators that better represent the face value of the variable of interest, such as likes and dislikes. To this end, techniques, such as the one presented by Dovidio and colleagues, comprises an inspiring illustration.

7.2. Issues for Future Research

Since the experimental procedures used in Pavlovian conditioning and EC paradigms often differ, it remains an open question whether the underlying mechanisms for the two forms of learning are different. In order to learn more about the possible differences, one would ideally need to show reliable dissociations between the two in a comparable task.

Although there are studies on how experimental extinction modulates the two types of learning in EC, no studies to date has investigated the long-term effects.

By comparing the extinction rate of responses to conditioned stimuli that acquired their emotional value through association with other higher order CS (as in EC) with those conditioned with a naturally aversive (or appetitive) event, more understanding can be gained of the representational format of emotional value.

Similarly to research on Pavlovian conditioning, possible dimensions of cultural and biological preparedness should be explored.

With the wealth of well developed protocols for Pavlovian conditioning and the subsequent control over the reward value of concrete and abstract CS, it should also be possible to better explore what variables implicit and explicit measures are sensitive to.

Although evaluating conditioning has provided examples of, at least, semi-naturalistic situations of affective learning, the ecological aspect of the experimental situations needs far more attention. Many researchers consider demand effects as the biggest obstacle hampering the success of this line of investigation. In response to this, more effort has to be directed to the further development of unobtrusive (implicit) measures. However, unless these clearly demonstrate that they measure what they claim to do (validity), their precision over time (reliability) is of little interest.

8. INSTRUMENTAL LEARNING

Unlike responses acquired through Pavlovian and evaluative conditioning, responses learned through instrumental conditioning are modified by their consequences. One formulation of the underlying process, also known as the Law of effect, states that behaviors that lead to a good outcome (rewards or the withdrawal of punishment) are repeated, while those that lead to a bad outcome (punishers or withdrawal of reward) decrease in frequency. An outcome that increases the likelihood of a particular behavior is referred to as a reinforcer. Instead of a newly formed association between the CS and the UCS, as in Pavlovian conditioning, an association is said to connect the reinforcer and the response. In order to maximize the reward value, an individual must explore the environment, which means a constant trade-off between explorations of new, risky, actions and exploitation of old, safe, knowledge (Krebs & Davies, 1997). Because novel stimuli are said to be intrinsically rewarding due to the evolutionary advantages of new discoveries (e.g. Rolls, 1999), exploratory behavior might consequently also be inherently rewarding for a similar reason. However, in order to take the most beneficial actions, the value of both immediate and delayed rewards have to be computed[14].

Instrumental conditioning allows the individual a great behavioral flexibility in order to attain its motivational goals. Unlike rigid responses, such like reflexes, arbitrary chains of behavior can be constructed in the search for reward or avoidance of punishers. With a flexible motor system and the immense cognitive capacity for innovative solutions, the variations of combined behavioral strategies that humans utilize in order to reach its goal are seemingly boundless. The resulting culture of goal attainment in human society is a reflection of this process. Still, in spite of its flexibility, instrumental actions that are overtrained seem to lose their sensitivity to many of the experimental manipulations that normally reinforce or

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[13] This link is often motivated by the idea that the spreading activation in a network of semantic nodes corresponds to the emotional affinity of the concepts that are represented within the network (for an example, see Greenwald et al., 2002). However, it is not clear in what way these associations necessitate evaluations.

[14] An influential theoretical accounts of the formal computations underlying this process is outlined by Sutton and Barton in their account of reinforcement learning (1998).

suppress the behavior, something that has been interpreted as the formation of a simple sensory-motor habit that functions in the same way as a CR (Dickinson, 1998).

However, it is important to note that stimuli or actions need not be rewarded in order for learning to occur. Since the time of Tolman, it has been known that animals do learn even without being reinforced. Early experiments by Tolman and colleagues (Tolman, 1948) compared different groups of rats, which during several days were either rewarded or not rewarded after having successfully completed a run through a maze. It was found that when both groups were rewarded in a later test-trial, they both performed equally well, which indicates that learning had occurred for both groups during the training, irrespective of the received reward. These experiments show that even in "lower" mammals with limited cognitive capacity, reward is not a necessity for learning to occur. Neither has there to be an explicit goal to learn in order to acquire new skills and knowledge, a phenomenon often referred to as incidental learning. The results also points to the fact that learning does not have to be manifested immediately subsequent it taking place, something commonly referred to as latent learning. Often it is not manifested until it is rewarded[15], as shown in Tolman's classical findings (see also Bandura, 1977).

8.1. Changing the Incentive Value

So far, the role of the individual as an active agent in the learning process has been less clear. However, as pointed out many times before, both humans and non-humans actively seek situations, and work for stimuli, that are rewarding - actually some research indicates that it is the work itself that produces the reinforcing value (e.g. Berns, cited by Tuma, 2003).

8.1.1. The Contrast Effect.

The value of a given reinforcer is bound to change as the internal state of the organism changes. Its reward-value also fluctuates as a function of its probability to occur, something that differs between times and domains (Lieberman, 2000). Findings of this kind support a relativist approach to the value of rewards. A phenomenon that well illustrates this relative status of reward is the so-called contrast effect (for a comprehensive review, see Flaherty, 1996). In short, if an animal performs a particular behavior in order to receive one unit of reward and then suddenly is rewarded with five units, its behavioral performance will increase to a much higher level than in an individual that received five units all along. The analogous phenomenon could be illustrated by a student's comparative decrease in learning performance in the class-room despite an increase in the amount of social rewards (e.g. praise) received from the teacher. Of course, although there could be uncountable reasons for this decrease in performance, one explanation could be an increase of social reward outside the classroom. In short, how well a new reward works as an incentive for work seems to be dependent on the difference in magnitude to a given reference point, rather than the absolute value of the new reward. Interestingly, these, and other similar findings, seem to go well along with theories in the field of decision making that argues that value is attached to goods or actions by its relation to a given reference point (e.g. Tversky and Kahneman's Prospect theory, 1981).

8.1.2. When the Timing is Right.

On a short time-scale, a clear link between the targeted behavior and the reward should be established in order to enhance learning. The faster the better is seems (Lieberman, 2000). Although this effect might be mediated by the abstractness of the reward (see also the findings on delayed versus trace conditioning, section 4.1.1), this general heuristic remains a powerful one. The distinction between immediate and delayed rewards is also visible in the brain. For example, a recent instrumental conditioning experiment that manipulated the delay of the reward in humans, reported that different brain areas were implicated in the immediate versus the delayed administration of fruit juice (Pagnoni et al., 2002).

Timing is also important in a longer time perspective. Although many of the basic schedules for reinforcement learning are adapted from training regimens employed during the heydays of behaviorism, they continue to prove useful as long as they are combined (and often modified by) with knowledge of the cognitive, emotional and motivational components that mediate their effectiveness. Studies with both humans and non-human animals show that partial, or intermittent, in contrast to a continuous, reinforcement is superior to make a specific behavior more independent of continued reinforcement. Of course, outside the lab, very few behaviors are rewarded each time they are performed. To further develop behavioral independence of the reward, the partial reinforcement should be based on performance, not on the passage of a predictable amount of time. In this respect, it is interesting to note that even when many educational systems are claimed to be based on behaviorist principles, they sometimes seem to be modeled on misconceptions of such principles. Just to take one example, in many educational institutions, reinforcements (e.g. exams, tests and grades) are given according to a fixed calendar-based schedule, often at the end of the semester or a program. This way of organizing the administration of reinforcements (i.e. according to fixed intervals) has reliably been demonstrated to discourage an independent and sustainable level of

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[15] This last remark reminds us of the hypothetical status of the notion learning itself - something that is recognizable only as measurable changes in performance.

work in reasonable doses throughout the learning period (distributed practice). Again, both permanent and transient factors (e.g. personality, cognitive organization, self-control strategies and context) mediate the effectiveness of the reinforcement schedule being used. Some of these mediating variables are further discussed in section 10.2.

8.2. Issues for Future Research

There is a lack of communication between social psychologists that study automatic behaviors and traditional learning theorists who have outlined detailed and mechanistic models for the formation of simple sensory-motor habits that are functional similar to conditioned responses.

In order to gain a better understanding of the role of expectancies that underlies the contrast effect, experimental manipulations that include both implicit and explicit reinforcements should be used.

There is a need for more systematic evaluation of how different reinforcement schedules affects learning performance in an educational setting.

As was indicated earlier, there has been much theorizing about the role of learning in the course of biological and cultural evolution. Still, much modeling is needed in order to specify the unique contributions of Pavlovian and instrumental conditioning in these developmental domains.

9. APPETITIVE STIMULI AND REWARD PROCESSING

Unfortunately, research on appetitive learning, or reward learning, as it often has been called, has only recently witnessed a surge in interest. Because it, in general, is easier to induce negative emotional states, such as fear, which are unconditioned responses to aversive stimuli, aversive learning has consequently dominated the field. The clinical community has sustained this trend with its interest in stimuli and learning situations that are relevant to phobic syndromes. However, in a similarly vain, a strong clinical interest in addiction has recently fueled an interest in the representations of rewarding stimuli and the underlying mechanisms of appetitive learning.

Certain unconditioned stimuli, such as food, social desirability and sex are naturally rewarding and referred to as primary rewards, while others acquire their value through being associated with primary rewards. Most stimuli and events acquire their value indirectly. Money and grades are examples of such secondary rewards that have a great impact on learning. Not only do they have a direct impact of what we learn, but they also serve as long term motivators that guide decisions on different levels of the neurocognitive system. Interestingly, many lines of recent reports have claimed that behaviors that are specific for humans, such as gambling, shopping, kleptomania involve the same reward related reward mechanisms as does having sex, eating and novelty seeking (Breiter, 2000; Knutson et al. 2001; Kim & Grant, 2001). In a functional perspective, it seems reasonable to assume that new phenomena can “hijack” systems that evolved to process other stimuli. On this note, it is interesting to observe that the data emerging from the research on addiction present clear sexual differences on the behavioral level. Men are approximately 100 percent more prone to submit to sex addiction, substance and gambling abuse than females, whereas women are in majority among those who shows addictive behaviors related to eating, shopping and kleptomania (Holden, 2001). There is little research on the underlying systems responsible for this sex specific pattern. Neither is there any research on how these differences in reward seeking behavior relates to the documented sex-differences in learning.

As more advanced and powerful neuroimaging techniques have been developed there has been an increased focus on the neural systems involved in reward-related representations and processes instead of the more traditional interest in the biochemical features. This development is not only helped by the new imaging techniques, but also by a better understanding of which brain circuits are associated with the release and uptake of certain neurotransmitters and hormones. The neurotransmitter Dopamine appears to be a crucial component in the rewarding value that is produced by stimulation of certain sites in specific brain areas (e.g. ventral tegmental area). These areas release dopamine into the Nucleus Accumbens. By its interaction with systems linking amygdala and the orbital frontal cortex (in primates), the release of dopamine influences the stimuli-reinforcement associations, which are being learned (Rolls, 1999, see also 9.1.). A strong motivation to activate this proximate reward system therefore is highly functional in serving the ultimate goals in a natural environment where stimuli and events in the surrounding have acquired a reinforcing value by the amygdala and orbital frontal cortex.

However, the story turns out to be somewhat more complicated. Although, the concept “reward” seems to be a label for a uniform phenomenon, recent research suggest that it can be broken down into different functional subcomponents. This insight is strengthened by both neural and psychological data. For example, Kent Berridge and his colleagues (Berridge, 2003; Berridge & Robinson, 1998, 2003) have in a series of experiments described three independent kinds of reward, related to emotion, motivation and learning, respectively. Each component is then divided into binary psychological components that roughly conform to the explicit-implicit distinction made earlier. Whereas previous sections have discussed explicit and implicit learning, the corresponding components relating to emotion will be outlined in section 9.1. The important feature with Berridge's suggestion is that the behavioral and cognitive consequences of a reward, depends on which component(s) is altered by the reward.

9.1. The Role of Dopamine in Reward Processing

9.1.1. One Substance – Many Tasks?

One much discussed topic in recent research on reward learning in cognitive neuroscience is the specific role played by Dopamine. Although, there is agreement on its importance, still much remains controversial. Since attention-inducing items have been shown to activate dopaminergic responses, some researchers have suggested that the dopaminergic response is trigged by the attention grasping qualities of the situation (Redgrave et al., 1999). However, since most non-rewarding, but nevertheless attention inducing situations, do not activate the same strong dopaminergic response, it has lately been suggested that it rather encodes the positively reinforcing aspects of the situation, or more specifically, a reward prediction error (Schultz & Dickinson, 2000, Schultz, 2001). Reward prediction error means that learning takes place when the actual reward does not match what is expected. Of course, as pointed out by Schultz, (2001), this does not exclude the possibility that there might be some specific kind of attention that is only associated with rewarded events. Still, these findings establish a clear link between the learning theory that describes the formal properties of error prediction, proposed by Rescorla and Wagner and neural populations in the frontal cortex and Dopamine (Fletcher et al., 2001).

9.1.2. Dopamine and Novelty.

Another strain of investigations has focused on the role of dopamine in novelty seeking. Instead of focusing on the deviations from expectancy as in the context of error prediction, Bevins and his colleagues (1999, 2001) define novelty more generally as "a change in stimulus conditioned from previous experience" (p.190). Further on, Bevins et al. suggest that novelty seeking should be conceptualized as a separate process from the reward derived by engaging in such behavior. Although there admittedly are several overlapping neural systems engaged in both the novelty seeking behavior and its rewarding aspects, there are also underlying differences. The most prominent one, which motivate the conceptual distinction between seeking and consumption of reward, is that the dopamine, more specifically Dopamine D-1, only seems to be engaged in the latter, rewarding, aspect of novelty seeking. Dopamine antagonists that block Dopamine 1 receptors do not decrease exploratory behavior and thus cannot mediate the discovery of novel objects. However, they severe the rewarding effects of these, measured as a preference for an environment that has been differentially paired with novel stimuli in the so called "place conditioning test" (for methodological details see Bevins & Bardo, 1999). However, as Bevins (2001) points out, these results are preliminary and the dissociation between these two aspects of exploring new stimuli needs to be further refined.

Rolls (1999) proposes a somewhat different role for dopamine in this reward system. Unlike Schultz et al, who argues that the dopaminergic activity carries a teaching signal by coding the error prediction and Bevins et al. who stresses its purely rewarding role, Rolls argues for a more modulatory significance in the reward system characterized by facilitating its operation. According to him, a strong argument that the activation of the dopaminergic neurons means "Go" rather than "Reward" is that also aversive events has been shown to activate this system. On a behavioral level Rolls actually claims, in stark contrast to Schultz, that the release of dopamine may be most closely related to the reward seeking (or stimuli avoiding) behavior (Rolls, 1999).

9.1.3. "Wanting" and "Liking".

The findings discussed above display some interesting similarities with the perspective taken by Berrige (2001, 2003). Berridge contests the popular view that dopamine is a "pleasure neurotransmitter" and argues, supported by a number of new studies, that activation in the human dopaminergic system is better correlated with motivational components, such as approach behavior and ratings of desire (for drug or food), than with the subjective rating of pleasure. In Berridge's terminology, motivational components of reward processing are (somewhat confusingly) referred to as either 'wanting' (with quotes) or wanting (without quotes). 'Wanting' denotes the implicit, and objectively measured, aspects of motivation, such as reward consumption and instrumental performance, whereas wanting refers to the cognitive (explicit) counterpart of this motivational urge. Again, 'wanting' differs, both on a psychological and neural level, from 'liking', the implicit and objectively measured emotional consequence of reward processing (e.g. facial expressions). As pointed out above, according to Berridge, dopamine release is not involved in generating emotional 'liking', but rather motivational 'wanting'. Whereas 'liking' is the implicit emotional consequences of reward, liking is the often accompanying hedonic feeling - its conscious (explicit) counterpart. Inherent in Berridge's claim is the idea that the 'wanting' aspect of reward processing is a more profound aspect in terms of generating instrumental behavior. As stressed earlier in this review, in most situations, implicit and explicit functions work in concert. However, psychopathologies, clever experimental manipulations, and even authentic situations outside the laboratory, can tease them apart (see sections 4.1.5, 5.2 and 7.1). It is of great importance to continue to investigate what effects different kinds of rewards (e.g. concrete and abstract) have on these different components (and potential interactions between them) and what the consequences are for learning.

Another important aspect in this biological context is the mediating role, which individual differences play in novelty and reward seeking. A recent review on the neurobiology of the structure of personality makes an excellent job in describing the specific relations between specific personality traits, such as extroversion, novelty seeking and dopamine (Depue & Collins, 1999). It is conceivable that this literature shows interesting links to the extensive research on individual learning styles (e.g. Gardner, 1993).

It hardly has to be mentioned that the bulk of the data cited throughout this section is based studies in extremely controlled experimental circumstances. Although pivotal to gain understanding of the precise neural and pharmacological underpinnings of reward seeking behavior and the rewarding value that is derived from it, the simple experimental manipulations that are used have few counterparts in the natural environment of most humans. Whereas participants know that rewards and the consequences of one's decisions in the lab environment, are comparatively insignificant, real-world decisions matter. Although, as pointed out earlier, many kinds of rewards seem to share the underlying processes, there are also clearly differences. On a behavioral level, this review has shown how higher order conditioning (e.g. evaluative conditioning) differs from first order conditioning and how the means of learning (e.g. through own experience, via observation or symbolic communication) can play an important role. In real life situations, rewards can be everything from (real or imagined) expectations of an improved social reputation to a thin mint cake after dinner. It can also be more diffuse, or unconsciously mediated, changes in our internal or external environment.

9.2. Issues for Future Research

So far, most research on reward processing has been conducted by investigators with a special interest in addiction and abuse. However, because the same underlying systems seem to be employed in a number of rewarding behaviors, studies of two kinds are needed. First, the scope of behaviors that are associated with this system has to be explored. Secondly, the more specific operations (in both neural and cognitive terms) involved in its activity have to be clarified.

Relating to the issue above, how do the underlying mechanisms that are activated by an anticipation of secondary, abstract reward (grades) differ from the anticipation of primary reinforcers? On a similar note, there is virtually no understanding of how the neurocognitive mechanisms that mediate immediate versus distant rewards differ. The abstractness of the reward, as well as the temporal interval between the behavior and the reward, certainly play important roles. By means of investigating the interaction between primary and secondary rewards on one hand and short versus long temporal intervals on the other, we would gain more knowledge of factors that are important for learning in more natural settings than has been possible so far.

Can these insights give us further knowledge about the mechanisms underlying error prediction?

How does novelty reward interact with reward derived from other primary and secondary reinforcers? And to what degree are the same brain mechanisms active? Moreover, what are the different mechanisms that make people approach new material and becoming rewarded by their exploration, respectively?

A vast body of research lays bare the proneness of the human cognitive apparatus to misjudge, and consequently misattribute, the causes of our own feelings and behavior. Research is needed to better understand the role of attributional mechanisms in reward processing (e.g. relating to the implicit/explicit distinction). Moreover, how misattributions can be avoided (or used) in order to aid learning.

As was pointed out earlier in the section on emotion, an important task for the research on learning in humans is to gain more knowledge of how reward is represented and to what extent it can be parsed into different components, how these components interact and in what way this bears on learning in applied settings?

10. RESEARCH TOPICS OF PRACTICAL INTEREST

10.1. Finding a Common Ground

10.1.1. Grasp All, Lose All.

A recent targeted article in Nature Neuroscience (Bruer, 2002), describes the striking absence of credible attempts to derive recommendations from neuroscientific research that could be applied in educational practice. This is the case, according to the author, for the good reason that there are very few such connections to be made. The emerging neuroscience and many of its branches are simply too immature to supply specific knowledge to educators. According to Bruer, there are many examples of premature attempts to bridge the gap in one stroke. These attempts often result in recommendations that are at best to general, and at worst, counterproductive to their (often) good intentions. A similar conclusion can be drawn after reading a recent report prepared for the educational ministry in the United Kingdom (Blakemore, 2000). The report presents little but the general statement that there is no neuroscientific ground for believing that early cognitive training of pre-school children on specific tasks is beneficial for later intellectual development. As with motor skills, children submitted to early training are soon being caught up with by others with a normal onset of training. The paramount task is rather to provide a rich, but not over-stimulating, environment as well as allowing for a normal emotional and social development without forced learning demands. Naturally, once the brain matured, motivated learning can produce great cognitive enhancements within the boundaries of the genetic endowment of the individual (see also Daniels & Plomin, 1996).

Another recent report, Understanding the Brain: Towards a New Learning Science, published by the Center for Educational Research and Innovation/OECD (2002), devotes the bulk of the text to praise the prospect of conducting interdisciplinary work that includes both basic neuroscience and educational practitioners. However, akin to the report by Blakemore (2000, see above), with some notable exceptions (see below), few concrete areas are described as constituting great promise for future interdiciplinary development[16].

10.1.2. One Step at a Time.

While the neuroscience of learning and emotion contributes with few suggestions for potential research programs that extend into the realm of education, findings on a cognitive/emotional and behavioral level do. The task then becomes to first link processes on these levels with neuroscientific data before well-grounded claims can be made about the links between neuroscience and educational research, including its applied branches. For example, this review has presented detailed findings that show that, on a behavioral level, people are predisposed to more readily associate certain categories of stimuli or events with specific, emotionally significant, outcomes. However, the outcome of learning also depends on how the learning is provided (e.g. through Pavlovian/evaluative conditioning, operational or social learning), who provides it, and, of course, who the learner is. Learning is context dependent and to learn an association in one external context (or bodily internal state) does not guarantee that it is manifested in another. Because emotional value, as well as meaning, is context dependent, learning should take place in so many contexts as possible to be successful. The timing of reinforcement is another crucial variable that influence attention, encoding and consolidation in the learning process.

However, although these issues might serve as good examples of themes that can be related to both basic learning science and educational practice, they need to be developed into more coherent programs of research in order to succeed. Interestingly, there are already a few lines of established research that currently show promise for such integrative work. These approaches all relate, in one way or another, to the basic findings reviewed in this paper. Importantly, they also include an extension directly into educational practice.

10.2. Four Examples

10.2.1. Cognition and Self-Control.

One of the areas of importance highlighted in the OECD (2002) report mentioned earlier, with specific relevance to our discussion of emotion, is self-control. The employment of self-control strategies is crucial for the well functioning in an environment, such as the one provided by the educational system. In order to concentrate, plan ahead, and being able to abstain from immediate rewards (e.g. taking a nap on the campus lawn on a sunny day instead of going to the lecture) that are in conflict with delayed rewards with a greater long-term impact (e.g. getting good grades), a range of strategies can be employed. People's strategies might be confined by their own cognitive apparatus (e.g. cognitive elaboration and imagery) or extended outside their body, employing social structures (Elster, 2000) or even external tools (for an overview, see Hall & Johansson, 2003)[17].

In a, now classical, longitudinal study by Mischel and colleagues (1989), a large sample of 4-year olds were faced with an experimental situation in which they had to choose between receiving a small immediate reward (cookies) or wait for a larger reward (more cookies). The remarkable finding was that the time which the children managed to postpone the immediate gratification (often with the help of self-generated cognitive strategies) correlated strongly with their scholastic performance and their parents reports of their capacity to cope with frustration and stress, as teenagers. This and a long line of similar studies, shows that an often employed successful strategy includes re-representing the tempting object or event in a more abstract "cool" form (for a review, see Metcalfe & Mischel, 1999). An important direction for future research in this area is the systematic investigation in the long-term impact of early teaching of the use of self-control strategies - be they cognitive, social or distributed[18].

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[16] A follow-up-project was launched in 2002 and is expected to be completed in 2005.

[17] Although not discussed in this context, self-control is a concept, as well as a set of techniques, with obvious moral biases that ought to be discussed.

[18] As some scholars (e.g. Rachlin, 2002) has suggested, the problem of self-control is not really be a problem of individual decisions and

Of course, apart from having the motivation to do so, the voluntary and conscious employment of these strategies presupposes an awareness of the "temptations", their causal impact, as well as which strategies to employ (and how to employ them) in order to exert effective self-control. However, given what we know about the functioning of people's minds, the many ways implicitly processed internal and external information bias our thoughts and actions, without access to conscious awareness (Wilson & Brekke, 1994), and the strong propensity for people to try to make sense of their feelings and actions by – not seldom – confabulation (e.g. Nisbett & Wilson, 1977), there are good reasons to believe that these conditions are rarely satisfied. This implies a great need of research on how to make these hidden processes more accessible and how this can be utilized in the learning and application of self-control strategies. Moreover, a continued research effort to increase our knowledge of the relationship between cognition and emotion in general, and how cognitively represented goals influence reward related processes in particular, is needed to better understand the mechanisms involved in self-control. Relating to these issues, it might prove useful to consult work done on cognitive appraisal and imagery (see e.g. Scherer, Schorr, & Johnstone, 2001).

Self-control[19] should however not be seen as something of value solely to the individual. The same principle is relevant in altruistic acts: when an individual gives up an immediate personal gain for the better of others. In addition, similar to repeated self-control over a longer period of time, reoccurring altruism can pay off (Rachlin, 2002). Obviously, self-controlling strategies can be of great importance in pro-social and moral education together with different ways of promoting empathy, which will be discussed next.

10.2.2. Emotion and Socio-Moral Education.

While self-control traditionally has been viewed mainly as a cognitive task to control the influence of emotion and motivation, another area of interest to the integration of findings from basic learning science and the applied field, instead stresses the adaptive value of emotional processes. In a recent review on emotion research, Caroll Izard (2002) delineates examples of how basic research on emotional processes can be translated into various learning programs to enhance children's socio-emotional competence and facilitate moral reasoning[20]. Although many of them specifically target children with emotional and social problems, the involved processes are of general value and apply equally well to normal populations. The examples discussed by Izard rest on two assumptions, both thoroughly supported in emotion research as reviewed in this report. The first assumption states that emotions have a profound influence on perception, cognition and action and the second emphasizes their adaptive value.

According to the Izard's extensive review, applied programs that aimed at emotional and pro-social education have utilized both positive and negative emotions. For example, Izard argues that cooperation games and role taking games, with easy achievable goals and success, increases positive emotions, something that facilitates the learning of pro-social behavior. When cooperation is successful, this results in an increased sense of social belongingness, which, in turn, boosts the likelihood of positive emotions and so on. In his review, Izard cites a host of well-validated programs that use these, and similar, means to improve pro-social behavior.

Similarly, negative emotions have been found to be important in the learning and maintenance of empathic emotional reactions, behavior and even moral reasoning. For example, by means of inducting a child to take the perspective of her or his victims, emotions involved in empathy and sympathy are activated. In the section on social learning, it was argued that observing somebody else's emotional expression, automatically elicit the corresponding emotional reactions in the observer. In the absence of real models to observe, imagery and active visualization can probably serve as a powerful help to achieve the same effects. By induction of negative emotions in perspective taking, it is argued, children better learn to discriminate among negative emotions and help them to represent their causes and motivational features. Empathy induced by negative emotions is also said to assist in the internalization of moral standards. More importantly though, evidence suggest that programs that comprise such exercises also facilitate the development of moral reasoning, something that is shown to have advantageous effects on both pro-social behaviors and self-esteem that persist over time.

A common feature in the approaches taken by Izard, is that they challenge the dominant social-cognitive position to learn how to solve social problems by "learning how to think". "Learning how to feel" seems equally, if not more, important in social contexts. The powerful impact that emotions have on cognition and behavior should be taken advantage of, because their potentially adaptive influence in our social lives is irreplaceable.

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acts, but rather of emerging patterns of behavior over time. Thus, how people view their own behavior seems to be an important theme for more research.

[19] It is interesting to note that self-control problems seem to be symmetrical, so that both to little and to much self-control can cause people difficulty.

[20] A series of recent accounts, presenting both behavioral and neural data, claims that emotion is an important ingredient of moral judgements (for a recent review, see Greene, 2003). It is even suggested that there are specific "moral emotions" (Haidt, 2001).

10.2.3. Ways to Motivate.

The research discussed above on self-regulation and pro-social behavior/moral reasoning, relates to skills other than those traditionally associated with learning in a classroom setting. Other areas research more directly targets the motivational features that facilitate conventional learning tasks. The study of the ways that extrinsic versus intrinsic motivation (e.g. Ryan & Deci, 2000a) exerts their impact on learning, illustrates an influential line of research in this tradition. Intrinsic motivation is defined as ”the doing of an activity for its inherent satisfactions rather than for some separable consequence” (Ryan & Deci, 2000b, p.3), whereas extrinsic motivation refers to doing something because if it’s separable outcome. Intrinsic motivation has been operationalized in a number of different ways, but the most common is through performance in the, so-called, “free choice” task. In this experimental manipulation, children are either given rewards or not. Then after being rewarded or not, the participant is told that no more work is needed and left alone. The time spent with the target task is used as a measure of intrinsic motivation (because there is no more extrinsic reward to expect). The interesting finding in a long line of studies is that extrinsic rewards seem to undermine the intrinsic motivation to work, learn and perform. Ryan & Deci (2000a) explain these results by proposing a model (the Cognitive Evaluation Theory, CET), according to which extrinsic rewards are interpreted by the participant as a source of external control, which is detrimental to the feeling of autonomy and competence – experiences necessary for the development of intrinsic motivation according to Deci and Ryan. Of course, given what we know about reinforcement learning, this claim does not stand unchallenged and, at a closer look, the empirical results do not look as clear as they might appear at first. For example, as pointed out by Eisenberger and his collaborators (e.g. Eisenberger & Cameron, 1996; Eisenberger, Pierce & Cameron, 1999), it turns out that the decrease is found mainly when rewards are tangible. The work in the “free choice” task is actually positively affected by most intangible rewards, and especially by unexpected such, among them, verbal praise. In addition, on uninteresting tasks, even tangible rewards seem to have an enhancing effect on intrinsically motivated behavior. Equally important is the finding that in contrast to instances when reinforcement is administered simply for completing the task, the reinforcement of progressively improved performance produced no loss of intrinsic interest. Eisenberger and Cameron (1996) claims that the basic mechanisms of instrumental and classical conditioning are sufficient to explain the different detrimental effects of tangible reward on task motivation. Nevertheless, it still remains an unresolved questions which cognitive variables are mediating the detrimental effects of tangible rewards on intrinsic motivation that are found, both in the lab and in educational settings. For instance, what in particular makes global notions, such as the feeling of autonomy, important in motivated behavior? Recently there are some attempts to resolve the question by modifications of the, previously proposed, CET with a stress on locus of control (Ryan & Deci, 2000b) or complete reformulations of the problem in terms of an approach/avoidance perspective (Covington & Mueller, 2001).

Another line of research that relates to the way motivation and emotion can be used to enhance creativity and industriousness on traditional cognitive tasks is suggested by Eisenberger (e.g. 1992, 1999; Hickman, Stromme, Lippman, 1998) and is proposed in stark contrast to the perspective taken by, among others, Ryan and Deci (see above). In his approach, referred to as learned industriousness, Eisenberg uses principles that are derived from more traditional instrumental learning, but extends his program by adding cognitive factors. His idea builds on the finding that the response-produced sensation of effort can be paired with a reinforcer, which causes that sensation to take on secondary reward properties. In other words, a procedure, analogous with the pairing an external stimulus with a reinforcer, conditions rewards value to the sensation of high effort and thereby reduces effort's aversiveness. Because the sensation of effort to perform a task acquires a reward value independent of the specific behavior that is involved, the generalization effect is broad, both in terms of the kinds of training tasks that contribute to generalized effort and the kinds of performance, which are influenced. In his comprehensive review, Eisenberg report a vast body of empirical findings (both human and non-human animal data) that rewarded effort, along these lines, contributes to stable individual differences in industriousness. However, learned industriousness does not only predict a higher task performance measured by the individual’s behavior, it also correlates with several cognitive parameters. In relation to our earlier discussion, it is especially interesting to note its facilitating impact on cognitively mediated variables, such as self-control and moral reasoning.

Naturally, learning is more than just acquiring knowledge and developing skills. The capability of directing and managing one’s own learning may be equally important, especially in higher education. A long line of research, dating back to Bandura (1977) on, what has been called, self-efficacy argues that individuals' beliefs about their performance capabilities in a particular domain are of important to both how well people learn, their learning goals (Bandura, 1997) and the ability to self-direct the learning (Hoban, Seraland & Raine, 2001). It is important to remember that the most effective strategy to motivate independent and efficient behavior might be heavily dependent on the specific behavior as well as its context. For example, in a review of different incentive systems on workplaces, Tyler (2002) reports that approximately 10 percent of the variance in cooperative behavior could be explained by changing the reward structures. Similarly, about 10 percent of the variance in rule-breaking behavior could be attributed to the estimate of the likelihood of being punished. These, and similar, findings suggest that there are many variables, beyond reward and punishment that are important to explain.

10.3 A Systematic Integration

In order to make the findings in basic learning science applicable to educational settings, much more preliminary work is necessary to better understand the presumably intricate connections between the fundamentals of emotion, motivation and learning and more global concepts, such as self-control, autonomy, interest, empathy and self-efficacy. In the previous section, four research programs were discussed that all are strongly related to the integration of basic learning science and education. Each one, in different ways, recognizes the importance of emotion and motivation. Self-control studies emphasizes cognitive strategies, Carol Izard's approach stresses the functionality of emotions, whereas the investigations of extrinsic/intrinsic motivation and learned industriousness, respectively, explore the impact of motivational variables on learning in a practical context.

A successful integration of basic and applied domains contains several equally crucially important components. First, educational applications have to be rigorously evaluated based on precise criteria for what they are supposed to achieve. Secondly, the particular manipulations that are successful should be specifically targeted and their components and functions should be linked to more basic components and functions that are better linked to a coherent theory (as pointed out in the beginning of this paper, relating to research on emotions and learning, theories that are compatible with an evolutionary meta-theory, have great prospect to succeed). Thirdly, the theory can then be used to derive predictions of new practical applications, which subsequently are evaluated and so on.

11. SUMMARY AND UNANSWERED QUESTIONS

Research on learning covers a vast range of topics. This review has focused on research on the role of emotion and motivation in basic learning processes. As the review has shown, although a lot of knowledge is accumulated, many unresolved questions remain.

On a general level, recent evidence has been produced in support of both a nativist and a constructivist approach to learning. The properties of emotion and motivation makes these internal states well suited if one wants to examine the design of mechanisms, such as those involved in different types of learning. In this respect it is important to first explicate the characteristics of emotion: how it is instantiated in the brain, the peripheral nervous system, in behavior and in the social environment.

Research shows that emotional factors influence learning on a number of different temporal stages in the learning process. This review discussed emotional and motivational influence on the pre- and post-encoding stages of the learning process, as well as its mediating role during encoding of new information. Relating to these lines of research, as well as most other basic investigations in learning, there is a tremendous lack of ecological validity in the experimental conditions used. This applies to contextual factors, the acquired knowledge, as well as to the learning source.

Experimental data from Pavlovian conditioning has provided much of the ground for what we know today about learning and emotion. Unfortunately, much of the research has been conducted on non-human animals, under very constrained experimental conditions and often involving aversive unconditioned stimuli. Much work has to be done to examine to what extent the same principles that govern, for example fear-conditioning, also holds for reward learning. Both in traditional conditioning and in social learning regimens, effort has to be done to explore the influence of many dimensions that research in other areas has argued to be of emotional and motivational significance, such as social dominance, desirability and attractiveness. Research indicating differences in the processes supporting different kinds of learning (e.g. that through symbolic and non-symbolic means) may, in its extension, turn out to be of importance in a variety of fields, such as education and psychopathology. Equally important is to continue to investigate the different components of reward, which sometimes independent of each other, affect our emotion, motivation and learning.

Again, research should capitalize on the new available techniques, such as functional Magnetic Resonance Imaging, which provides us with clues about what emotional and cognitive components are involved in different aspects of learning, as well as in influencing how, what, and why, we forget. Imaging techniques also enables us to compare the vast host of work conducted on non-human animals with that of living, learning, humans. Cross-species comparisons may provide additional information about the basic functional similarities in brain regions of specific interest to learning, such as the temporal lobes and the prefrontal cortex. Equally important is to increase the understanding of the interplay between different functional structures. In addition, this might contribute to the understanding of the most rudimentary building blocks and dimensions utilized by learning, both symbolic and non-symbolic.

Data that introduce dissociations between processes that includes implicit versus explicit representations in relation to learning situations with relevance for every day functioning is currently attracting a lot of attention. A related issue is the need to develop valid and reliable means of measure implicit and emotional aspects of what is learned.

Both humans and other animals use social communication as a means to acquire emotionally significant knowledge. Evidence of convergent cognitive and neural underpinnings of peoples' own emotional experiences, and their perception of others, promises a surge in the interest of learning through social means.

A recurrent theme throughout this review is the patchwork of functional neural regions or circuits that contribute to specific functions. One of the most central questions for cognitive neuroscience is to understand how their neural correlates communicate (Rolls, 2002). However, the role of specific brain systems can be understood only together with the work of parsing psychological concepts, such as reward, into its specific components and probing each component in turn (Berridge, 2003). In relation to learning on a neural level, the role of dopamine has received a lot of interest. However, more investigations are needed to settle the controversies about its specific role in the regulation of learning and behavior.

This review stresses the importance to explore the dimensions that learning on different levels of complexity is sensitive to. This applies to the physical dimensions, such as the timing of events (see, for example, the differential effects on behavior mediated by the reinforcement schedule outlined above), the content of the knowledge and the model or instructor that conveys the information. It is important to be aware of the omnipresence of emotional feedback in the learning situation and the constant dependence of the goals that motivate the learner. In this respect, it is what really motivates the learner, not what is supposed to motivate her, which works as an incitement for learning. However, as has become visible throughout this review, current research shows that what motivates us can be affected - by learning - on one level or another.

Related to the discussion above concerning the importance of multiple learning contexts, one perspective that is lacking in this review is the discussion of specific changes in the structure of complex knowledge (concepts and categories) that are infused by emotion and motivation. A closer look at the organization of knowledge, provided by both behavioral, neural and simulation data, suggests that representations of concepts, objects and psychological states are intimately connected with other, distributed, representations, each encompassing specific modality and functional-specific properties (Barsalou et al., 2003). For example, the word “orange” may be linked to both emotional representations of its value, information about its sensory qualities, representations of acts that can be performed on it, and so on. In a similar fashion, the representation of an emotion might be tightly connected to both semantic and episodic abstractions, as well as an emotional instantiation – a feeling - of that same state. This model of a distributed, but tightly connected, representational network is informative for how people learn and thus for how people should be best taught. Still, in a simple form, it might be unsatisfying as a model of the emotional impact on learning because it does not tell us how (and whether) emotions fundamentally change the representation of other (cognitive) kinds, or whether they just boost the weights between concepts, and thus make them more readably accessible and salient.

Trying to cover all aspects of emotional and motivational influence on learning is however an insurmountable endeavor, and hence the decision to constrain the scope of this review severely – a decision that turned out to be, not only unavoidable, but also good. The focus of this review has been on findings revolving around basic mechanisms of learning, mostly because here the involvement of emotion and motivation is best known, but it has also tried to extend the implications of these findings beyond basic experimental research. However, to further facilitate a fruitful integration of knowledge in basic science and practice, many links are yet to be established. Even if it is impossible to bridge all islands of knowledge in one stroke, there is currently great progress in establishing links between different fields and levels of investigation. As long as there is learning (and motivation!), there is hope.

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