CANADIAN PSYCHOLOGICAL REVIEW
PSYCHOLOGIE CANADIENNE
Vol. 20, No. 3, July 1979

FRUSTRATION, EXPLORATION, AND LEARNING

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ABSTRACT

D. E. Berlyne's principle that uncertainty leads to exploration is extended to situations involving frustrative nonreward. Both empirical evidence and logical analysis support the frustration-exploration hypothesis, which posits that uncertain frustration leads to exploration, whose primary function is to broaden the scope of response selection. The facilitative effects of frustration-motivated exploration in learning are documented, and their implications for education are discussed.

One of Daniel Berlyne's abiding interests was in curiosity and exploration. Perhaps, among his many significant contributions to psychology, his work in this area has made the greatest impact. His 1960 monograph *Conflict, Arousal and Curiosity* is among the 100 books most cited by social scientists (Garfield, 1978). Few will disagree that it is mainly due to Berlyne's influence that exploration or information seeking has been elevated to the same status as hedonism as one of the primary sources of motivation. In view of the prevalence of information seeking (Berlyne, 1966), a case may be made that it is a more important motivation than the pursuit of hedonic goals.

In paying tributes to Berlyne, I cannot help but reminisce on the good old days of being a graduate student at the University of Toronto, when both Daniel Berlyne and Abram Amsel were on the psychology faculty. To be taught by these two eminent psychologists was to be influenced by them in a profound way. Although different in many ways in their approaches to research, both of them demonstrated a remarkable degree of independence of thought in the midst of shifting paradigms and changing fashions in psychological research. While Amsel concentrated his research efforts in well defined problem areas, Berlyne's own curiosity led him to explore new frontiers in psychology. One learned from Amsel how to rigorously and thoroughly investigate a phenomenon; one learned from Berlyne how to see old problems in new lights and how to detect connections in seemingly unrelated areas of research. Both of these approaches have influenced my own research career, and these influences have contributed to the present paper which attempts to interface frustration and exploration.

In the past ten years, I have done several studies on the problem of persistence and frustration, even though such research no longer attracts the attention it once did. Having carefully observed hundreds of rats in a great variety of frustrating situations, I cannot help but notice the prevalence of exploratory behaviour. For example, in a runway situation, partial reinforcement increases sniffing, exploration of irrelevant holes on the runway walls, and variation of routes leading to the goalbox (Wong 1977a, 1978a). In this article, I will document the existing evidence supporting the frustration-exploration hypothesis. More specifically, I will attempt to demonstrate that (1) uncertain frustration leads to exploration, (2) frustration-motivated exploration primarily consists of response-variation, and (3) this type of exploration plays an important role in instrumental learning. However, before we examine the evidence and arguments in support of the frustration-exploration hypothesis, we should first examine exploration as a concept and past research on this topic.

Portions of this paper were presented in a symposium in honour of the late D. E. Berlyne at the Canadian Psychological Association Meeting in Vancouver, July, 1977. The paper was written while the author was a visiting scholar at the University of California, Los Angeles. It was supported by Grant 3A0701 from the National Research Council of Canada, and a Canada Council Leave Fellowship. Requests for reprints should be addressed to P. T. P. Wong, Department of Psychology, Trent University, Peterborough, Ontario, K9J 7B8.

Uncertainty, Conflict, Curiosity and Exploration

A great variety of behaviours come under the rubric of exploratory behaviour. In rats, orienting responses, locomotion, manipulation, rearing and sniffing etc. all may be classified as exploratory behaviour. Berlyne (1960) has broadly defined all "responses that alter the stimulus field" as exploratory behaviour (p.78) and added that "their principal function is, in fact, to afford access to environmental information that was not previously available . . . they widen the scope of stimulus selection enormously" (p.79). Hinde (1970) has pointed out that "even within one species the types of behaviour which come within the broad category of exploration or investigation are diverse, and it is difficult to give a more precise definition than that they are such as to familiarize the animal with its environment or with a source of situation." (p.351).

From the above definitions, it is clear that exploration is typically defined in terms of its function, which is information seeking. Thus, exploration and information seeking behaviour have often been used interchangeably. It is also clear that the focus of the above definitions is on the stimulus dimension, and only behaviour that increases the animal's contact with the external environment is considered as exploration. Given such a stimulus-orientation, it is only natural that past research on exploration has centred on stimulus properties as determinants of exploration. However, information seeking need not necessarily be directed to external sources of stimulation. When an animal is placed in a puzzle box (see Guthrie & Horton, 1946), it typically explores both the immediate physical arrangements of the box as well as its own response repertoire until it performs the correct response that releases the latch. In this case, exploration has the function of widening the scope of both stimulus selection and response selection. Response-oriented exploration may be conceptualized as trial and error learning, hypothesis testing, or the variable, appetitive component of instinctive behaviour, depending on one's theoretical framework. In each case it is an important integral part of exploration in situations where the necessary information for the solution of the problem resides in the animal's own response repertoire. Therefore, a more comprehensive definition of exploratory behaviour should include all responses that increase the scope of stimulus selection and/or response selection.

Berlyne has differentiated two major classes of exploration:

> On the one hand, when an animal is disturbed by a lack of information, thus left a prey to uncertainty and conflict, it is likely to resort to what we may call *specific* exploratory responses. These supply or intensify information from particular sources – sources that can supply the precise information that the animal misses. The condition of discomfort, due to inadequacy of information, that motivates specific exploration is what we call "curiosity". In other circumstances, an animal seeks out stimulation, regardless of source of content, that offers something like an optimal amount of novelty, surprisingness, complexity, change or variety. For this kind of behavior the term *diversive* exploration has been proposed. (Berlyne, 1966, p.26).

The main thrust of Berlyne's work has been on curiosity-motivated specific exploration. According to Berlyne, the two antecedent conditions for curiosity, namely, uncertainty and conflict, are very closely related. He states that "situations in which uncertainty is of psychological importance are situations of conflict" (Berlyne, 1960, p.29). In his last writing on this subject, he continued to stress the affinities between these two antecedent conditions. "We can speak of 'subjective uncertainty', whenever somebody is inclined towards a number of competing expectations, beliefs, images or more generally, representations of a particular situation, without being in a position to commit himself to one of them and to reject or suppress the others" (Berlyne, 1978, p.143).

Most of the work done on specific exploration has focused on perceptual curiosity, which is aroused by certain properties of external stimulus patterns, and which is directed toward stimulation capable of reducing or removing uncertainty (e.g., Berlyne, 1950, 1955, 1958). However, Berlyne has extended his analysis of specific exploration to epistemic curiosity, where curiosity is motivated by conceptual conflict, and the responses are aimed at stimulation capable of dispelling uncertainty as well as providing information for storage in symbolic structures (Berlyne, 1965).

Two defining characteristics may be abstracted from curiosity-motivated exploratory responses. First, they are *stimulus-oriented* rather than *response-oriented.* They are directed to some sources of external stimulation rather than to various alternatives in the organism's response repertoire. They are best described as stimulus seeking behaviours. Secondly, they seem unrelated to various biological drives such as hunger, thirst, and pain, and there is no evidence that they are dependent on secondary reinforcement. In short, they are simply motivated by curiosity, which should be conceptualized as a primary motive in its own right.

In spite of his emphasis on the intrinsic motivation of stimulus seeking behavior, Berlyne also recognizes the ecological importance of exploration. Commenting on various kinds of exploratory activities, he wrote:

> In all these activities, sense organs are brought into contact with biologically neutral or "indifferent" stimulus patterns – that is, with objects or events that do not seem to be inherently beneficial or noxious. Stimulus patterns encountered in this way are sometimes used to guide subsequent action aimed at achieving some immediate practical advantage. An animal looking and sniffing around may stumble upon a clue to the whereabouts of food. (Berlyne, 1966, p.25).

At this point, one is tempted to raise a number of fundamental questions. What will the organisms do when uncertainty and conflict are present in events that are inherently beneficial or noxious? Is specific exploration in this context different from the kind of curiosity-motivated exploration described earlier in the paper? The following represents an initial attempt to answer these difficult and very involved questions, by extending Berlyne's analysis of specific exploration to schedules of reinforcement. More specifically, I will examine exploratory behavior in three kinds of schedules which clearly involve uncertainty and conflict.

Frustration-motivated vs. Curiosity-motivated Exploration

On the basis of logical analysis, one can readily identify three kinds of schedules in which some elements of uncertainty and conflict are present: early extinction, successive acquisition and extinction, and partial reinforcement. During the early stages of extinction, the organism can not be sure whether reinforcement is still attainable, and should experience an approach-avoidance conflict. In the case of successive acquisition and extinction, uncertainty and conflict should be created by unpredictable changes in the schedule. Shaping is a good example of successive acquisition and extinction. The shaping procedure typically involves successive steps or approximations to a target behavior. Once an organism has successfully acquired the first step, it is no longer reinforced until it emits a response that meets the requirement of the second step. This procedure is continued until the organism is able to emit the target behavior. It is apparent that whenever the criterion for reinforcement is changed, the organism has no way to know why reinforcement is discontinued, nor does it possess the information to predict the reinstatement of reinforcement. Finally, in partial reinforcement situations where reinforcement is irregular and unpredictable, the organism is naturally uncertain about the outcome and has conflicting expectancies.

It is not difficult to recognize that all three situations involve frustrative nonreward, defined as the occurrence of nonreward in a context that has been associated with reward (Amsel, 1958, 1962). It is the presence of frustrative nonreward that distinguishes these situations from other situations of uncertainty and conflict. I will now turn to some evidence that is consistent with the hypothesis that uncertain frustration leads to exploration.

Extinction. Psychologists have known for some time that the onset of extinction increases response variability (Antonitis, 1951; Kuo, 1922; Guthrie & Horton, 1946; Skinner, 1938). For example, Skinner (1938) observed that variation in the force and duration of lever pressing was greater during extinction than during conditioning, and commented that extinction serves to increase the scope of responses for selective reinforcement. In other words, during extinction the organism will explore alternative response topographies to increase the likelihood of reinforcement. With prolonged extinction, the elements of uncertainty and conflict should no longer exist, because consistent and repetitive presentations of nonreward should eventually convince even the most optimistic creature that reinforcement in the situation is no longer available. At this stage, the rate of instrumental responding should decrease to zero. Recently, it has been pointed out that unrelenting frustration could eventually lead to "helplessness" and "depression" (Wong, 1978a, b; Wong, Note 1).

Shaping. Success in shaping importantly depends on the discrepancy between successive steps of approximation. If the discrepancy is too great, the organism may cease to emit instrumental responses and become "helpless". On the other hand, if the discrepancy is very small to minimize frustration, shaping might be slow and difficult. It is conceivable that if the successive criteria for reinforcement are too lenient, organisms may become so "spoiled" that they fail to learn the target behavior. In the past few years, I have observed several instances of failure to shape a rat by students due to this reason. For shaping to be efficient, there should be an optimal discrepancy between successive steps for the exploratory tendency to reach its maximum strength.

Partial reinforcement. There is now sufficient evidence to suggest that partial reinforcement produces greater response variability than consistent reinforcement. Supporting evidence has been obtained in children (McCray & Harper, 1962), college students (Newberry, 1971), and rats (Wong, 1977a, b). It has been suggested that more response elements *r* are sampled from the generic response class or a population *R* under partial reinforcement than under consistent reinforcement conditions (Schoenfeld, 1968).

Response space vs. stimulus space. In all three situations of frustration, the exploratory responses observed are primarily response-oriented. It may be argued that in some cases response variation is accompanied by stimulus-oriented exploration. For example, by increasing the variability of routes leading to the goal box, the animal inevitably increases its contact with the environment. However, there are also situations where response variation, such as varying the vigor, duration, and latency of responses (Skinner, 1938) and transition of responses (Newberry, 1971), is not accompanied by a parallel increase in the scope of stimulus selection.

On the basis of logical analysis, there is no *a priori* reason why exploration should be directed to external stimulation exclusively. In the case of perceptual curiosity, where uncertainty clearly stems from the properties of external stimulus patterns, it is only logical that exploration be directed to the stimulus space. However, in the case of frustrative nonreward, the source of uncertainty may be due to a change in the environment or the inadequacy of the response; therefore, it is most adaptive to explore both the stimulus and response dimensions. In fact, when the same response in the same situation no longer produces the same outcome, the dominant tendency may be response variation. For example, when the same set of responses fails to start a car, the dominant tendency is usually to vary the strength and duration of responses. Therefore, on the basis of review of the literature and logical analysis, it may be hypothesized that frustration-motivated exploration is primarily response-oriented. This hypothesis is not central to the proposition that frustration leads to exploration, but is an interesting hypothesis that helps differentiate two types of exploration.

Information Seeking vs. Hedonic Pursuit

Another difference between curiosity and frustration-motivated exploration is that in the former organisms appear to engage in information seeking for its own sake, whereas in the latter information seeking serves the dual function of reducing uncertainty and securing an external reward. One may wonder whether frustration-motivated exploration will still persist, if it has the effect of reducing uncertainty, but increasing frustration. In other words, is information seeking mainly subservient to hedonic pursuit in situations of ecological importance? This question deals with a very fundamental issue in the psychology of motivation, namely, the relative importance of information seeking as compared to hedonism. Berlyne (1966) seems to suggest that information seeking aimed at uncertainty reduction may be more important than hedonism. He observed that a hungry rat will spend time investigating a novel feature of the environment before turning to food, and a bird may approach a strange object at the risk of its own life. Of course, one can also readily cite instances where curiosity not only kills the cat, but also has taken the life of many a journalist. From the perspective of attribution theory, Weiner suggests the possibility that information seeking may be manifest even when it conflicts with the pleasure principle (Weiner, 1979). To settle this issue, one needs to pit information seeking against pleasure seeking, such that any gain in information is counteracted by a loss in the fulfillment of hedonic needs.

In real life, it is not difficult to think of situations where people would seek out information at the risk of receiving bad news. For example, patients want to find out whether their illness is curable, and aspiring students want to know whether they really have what it takes to be successful in certain professions. There are also numerous instances in which information is valued more than pleasures and "truth" is placed above life itself. In the laboratory, it is not difficult to set up situations where exploration has the effect of gaining information (e.g., increasing the predictability of an outcome), but reducing the likelihood or magnitude of reinforcement. Similarly, reduction of uncertainty may be offset by an increase in the likelihood or intensity of punishment. Clearly there are boundary conditions within which information seeking overrides hedonic pursuit. If research can demonstrate that in a variety of situations the need for information outweighs hedonic needs, it would bring to a triumphant conclusion the revolution spearheaded by Berlyne over two decades ago in the psychology of motivation.

Reward Reduction and Exploration

From the perspective of frustration theory, reward reduction is also an antecedent for frustration (Daly, 1969; DiLollo & Beez, 1966). One study with college students demonstrated that reduction in reward magnitude increased the variability of responding as compared to the control group that did not undergo reward reduction (Boroczi & Nakamura, 1964). In an early study of shifts in quality of reward, Elliott (1928) observed that a downward shift resulted in an increase in blind alley entries in the rats, and suggested that these wrong entries might represent a search for the now missing preferred reward. In other words, reward reduction, like frustrative nonreward, may also promote exploration as long as there is an element of uncertainty in the situation. Prolonged or predictable reward reduction should not lead to exploration.

Recently, in an interesting study, Flaherty, Blitzer, and Collier (1978) studied openfield behaviours elicited by a reduction of sucrose concentration in drinking water. Their purpose was "to determine whether any increases in activity that occurred subsequent to the shift might be interpreted as frustration or as exploratory related responses." (p.430) By pitting frustration against exploration as alternative interpretations of increased activity, they apparently assumed that frustration leads to only general arousal but not exploration. Their hypothesis was likely guided by past research on frustration effects, which focused on general arousal or the invigoration effect (Amsel & Roussel, 1952; Scull, 1973). In contrast to Flaherty *et al.* the present frustration-exploration hypothesis assumes that frustration induces general arousal as well as exploration; in fact, exploration may be considered as one of the several behavioural manifestations of arousal induced by frustration. Flaherty *et al.* reported that reward reduction significantly increased ambulation and wall rearing, but did not have any significant effect on the sampling of alternative water tubes. They concluded that reward induced frustration-related behavioural arousal, but not exploration. However, the authors recognized that "wall rearing and ambulation could also be interpreted as reflecting exploratory tendencies on the part of the animals". Thus, their findings could also be regarded as supporting the frustration-exploration hypothesis. The absence of frustration induced response variation (i.e., licking alternative water tubes) may be due to the fact that licking is a consummatory response. In most studies, frustration induced response variation is observed in instrumental responses such as lever pressing or running, although frustration induced displacement pecking in the Barbary dove has also been reported (McFarland, 1965, 1966). More research is needed to determine whether frustration-motivated response variation can be obtained in a number of consummatory responses.

The Role of Frustration-Motivated Exploration in Learning

Berlyne always took a keen interest in the general question concerning the role of exploratory behaviour in learning. In fact, his latest and unfinished book was entitled *Curiosity and Learning* (Berlyne, 1978). The importance of curiosity-motivated exploration (e.g., investigatory or orienting reflex) in learning has already been established (Pavlov, 1927; Sokolov, 1963). The role of frustration-motivated exploration in learning is much less known. In this section I will present some recent findings demonstrating the importance of frustration-motivated exploration in a number of learning situations.

Frustration and shaping. As mentioned earlier, the shaping procedure typically involves successive acquisition and extinction, hence, frustration. Recently, an experiment was conducted to determine whether frustration indeed facilitates shaping (Wong, Note 1). Two groups of rats served as subjects. Controls received food-magazine training in their home cages, while Experimental subjects received the same training in a Skinner box. Subsequently, all subjects were tested in the Skinner box for autoshaping of a lever pressing response. Since only the Experimental subjects had received free food pellets in the Skinner box, they should experience frustrative nonreward when food pellets were no longer freely available during lever training. Frustration-motivated exploration should result in faster learning. This prediction was clearly supported in that Experimental subjects had a shorter latency in their first lever response and acquired the lever pressing response at a faster rate than the Controls. While all the Experimental rats acquired the response very readily, several Controls failed to learn even after several sessions of exposure to the Skinner box. Their failure to learn was partly due to the fact that their exploration was primarily stimulus-oriented; these rats sniffed and inspected different aspects of the Skinner box including the lever, but rarely pressed it strong enough to activate the feeder. One could further assess the role of frustration in shaping and autoshaping by manipulating prior reward experiences such as the magnitude and the frequency of food pellets during magazine training.

Frustration and higher-order operants. According to Wong (1975), higher-order operants are capable of modifying or controlling schedules of reinforcement. This class of operants may be best described as controlling operants, because they control the contingencies for other responses (Catania, Note 2). In a recent experiment (Wong, 1977c), if the rat switched to an adjacent lever on the nonpreferred side, the ratio requirement for the centre lever was reduced. Rats acquired the controlling operant only when they encountered a period of extinction which increased the tendency to explore adjacent levers.

Frustration and creativity. In a very interesting study by Pryor, Haag and O'Reilly (1969), a porpoise was trained to be creative. It was reinforced only when it emitted a novel behaviour. In other words, the porpoise would be repeatedly frustrated until it emitted a behaviour that had never been displayed before. As a result of this shaping procedure, the porpoise greatly expanded its response repertoire. The success of this creativity training procedure is clearly dependent on frustration-motivated exploration. Selective reinforcement of novel behaviour is possible only when nonreinforcement or frustration forces the porpoise to stretch its response space and exhaust its response repertoire. More recently, Wong (1977b) was able to train rats to vary their response routes from trial to trial by using a similar procedure. Additional evidence that frustration may increase creativity was reported by Frost (1976). He reported that mild frustration seemed to increase creative behaviour in all components except originality as measured by the Torrance Tests of Creative Thinking. Unfortunately, the author did not use the multivariate analysis of variance to test for significant differences.

Frustration and concept learning. The facilitative effects of frustration-motivated exploration have also been demonstrated in a series of experiments on concept learning with public school children as subjects (Wong, Note 4). The learning task was to abstract different relational rules from different sets of exemplars. The rules included *identity* (all elements between two stimulus patterns being identical), *non-identity* (all elements between two stimulus patterns being different) and various conditions of *partial identity* (e.g., same color, but different shapes and different orientations). An abstraction-production paradigm of concept learning was used. That is, the youngster was first asked to abstract the relational rule from a set of exemplars, and then asked to produce more instances of this same rule. The children were assigned to either the Demonstration condition or the Strategy condition. Under the former condition, if the child made an incorrect response, the experimenter would demonstrate and explain step by step how to produce a correct instance of the rule, thus protecting the child from further failure and frustration. Under the latter condition, when a mistake was made, the child was encouraged and guided to explore other responses until a correct production was made. The intent of the latter procedure was to provide opportunities for the child to learn a constructive strategy of coping with failure and frustration. The results showed that concept learning was superior under the Strategy condition where frustration-motivated exploration played an important role in the learning process.

Frustration and stimulus-oriented exploration. I have just documented empirical findings demonstrating the constructive role of response-oriented exploration in a variety of learning situations. The picture would not be complete without reporting that frustration may also facilitate learning through stimulus-oriented exploration. In several experiments, Sutherland (1966) and McFarland (1966) have shown that rats and doves learned more about incidental or irrelevant cues under partial reinforcement conditions, and exhibited faster learning in a subsequent situation where previously irrelevant cues were made relevant. They hypothesized that when no stimulus analyser consistently predicts reward the animal should try out many different analysers. In other words, frustrative nonreward should switch attention to different aspects of the environment. Sutherland (1966) has suggested that partial reinforcement increases the breadth of learning. Thus, frustration not only compels the animal to explore alternative responses, but also draws their attention to hitherto unnoticed features of the environment.

Persistence and learning. The importance of persistence in learning can not be overemphasized. Englemann (1969) has rightly pointed out that "persistence is particularly important in a new learning situation. . . . A child who has not been taught that he will succeed if he continues to try will tend to interpret his first failure as proof that he cannot succeed. . . . The child who has been taught that persistence pays off views the failure in a different way. . . . It is extremely important to teach children the persistence concept." (p.94)

However, it is important to distinguish between response persistence and goal persistence (Wong, 1977a). The former refers to perseveration in a response that is no longer appropriate. The latter refers to perseverance in the pursuit of a goal by whatever means. Response perseveration is frequently self defeating, whereas goal persistence often pays off. In partial reinforcement situations, occasional frustration elicits a goal-oriented exploratory response as illustrated by the observation that rats vary their routes leading to the goalbox (Wong, 1977a). Reinforcement of this reponse tendency results in it being conditioned to frustrative cues. Therefore what is learned in a partial reinforcement situation is primarily goal persistence. More specifically, what is conditioned to frustrative cues may be called a try and vary coping strategy (Wong, 1977a) because it increases goal persistence in a variety of situations (Wong, 1977d; Wong & Amsel, 1976). The word strategy does not imply higher cognitive processes, but rather denotes that what is conditioned is not a specific response topography but a general response rule (Wong, 1977b). This kind of learning is consistent with Ansel's general theory of persistence (Amsel, 1972), which posits that the counterconditioning of an ongoing behaviour to any disruptive event will increase the persistence of any ongoing behaviour in subsequent disruptive situations. Guided by this notion, we have demonstrated transfer of persistence across different situations and different response systems (Amsel, Wong & Scull, 1971; Amsel, Glazer, Lakey, McCuller, & Wong, 1973; McCuller, Wong & Amsel, 1976; Wong, 1971, 1977d). Such transfer of persistence suggests to us that what is conditioned to frustrative cues is a general response rule rather than a specific response topography; in other words, the kind of persistence that is generalized is goal persistence rather than response persistence.

The only study that appears to contradict the above rule learning notion is that reported by Ross (1964). He found that rats given partial reinforcement training for climbing subsequently continued to exhibit the climbing response when running was being extinguished. One may resolve this apparent discrepancy by pointing out that as the try and vary response rule is being activated, alternative responses that have been previously reinforced should have a higher probability of occurring; therefore, it is not surprising that the previously partially reinforced rats should exhibit the climbing response, which was a subset of goal approach responses in the runway, when they tried various alternatives in the face of frustration. One may also argue that if Ross provided measures of goal persistence (i.e., frequency of goal entry or number of trials to goal avoidence), these rats should show greater goal persistence than their continuously reinforced counterparts. To really settle the issue whether rule learning will override response learning in the transfer of persistence, we need a situation where a specific response and the general persistence rule are pitted against each other. For example, we can first give rats partial reinforcement training for barpressing, then continuous reinforcement training in a runway. When the running response is being extinguished, a bar is made available in the startbox. Will the rats persist in barpressing or in approaching the runway goalbox in this situation? If rule learning predominates, rats should persist in varying their behaviour patterns that lead to the goalbox.

Certain vs. uncertain frustration. Berlyne (1960) suggested that conflict and frustration may motivate thinking, epistemic curiosity, and the acquisition of knowledge. I have shown that the beneficial effects that accrue to frustration are primarily attributable to frustration-motivated exploration. One may wonder why frustration has been generally viewed in a negative light (Lawson, 1965). This may be, in part, due to the negativity bias of psychologists who seem to be particularly tuned to the dark side of the human nature or events (see deCharms & Muir, 1978). For example, agitated behaviour during extinction has been described as neurotic or pathological (e.g., Miller & Stevenson, 1936). From my perspective, extinction induced behavioural arousal may represent the mobilization of energy and resources to cope with frustration and conflict. A second reason may be that the negative affective consequence of failure is often not balanced by the positive affective consequence of overcoming failure. Finally, it may be due to the problem of not differentiating between certain and uncertain frustrating events. In the former case, the causes of frustration are both stable and uncontrollable. In the latter case, there is the likelihood of success if one tries long enough. When frustration is unrelenting and unmitigable, as in prolonged extinction or a long history of failure, one may become a victim of helplessness. However, when frustration is occasional and/or controllable, it provides challenge (Berkowitz, 1964; McClelland, 1969) and promotes learning.

The beneficial effect of frustration-motivated exploration on learning has been primarily observed in instrumental learning situations. Whether uncertain frustration also has facilitative effects on a wide range of learning situations, such as problem solving, memory retrieval, information processing, remains an empirial question. As well, the generality of the frustration-exploration hypothesis remains to be tested in different species.

It should be noted that since uncertainty is an integral part of frustrating situations that are capable of promoting exploration, one may wonder to what extent the internal motivational state of curiosity as instigated by uncertainty contributes to exploration. It is possible to experimentally assess the relative contribution of frustration and curiosity to exploration by independently manipulating the degree of uncertainty through varying reward and nonreward sequences (Habu & Ono, 1976) and by manipulating the magnitude of frustration through varying the magnitude and frequency of reward as well as drive level. Apart from the issue of overlap between two motivational states, there is also the interesting issue with respect to the similarities and differences between frustration and curiosity – a question that also awaits further research.

The Frustration-Exploration Hypothesis and Education

Berlyne's research on curiosity-motivated exploration has already been applied to education to enhance creativity and intrinsic motivation (Day, Note 3; Day, Berlyne, & Hunt, 1971). Frustration-motivated exploration has perhaps even wider implications for education, especially in educational systems, where failure is viewed as an unnecessary evil to be circumvented whenever possible. Skinner's (1959) contention that error responding is an unnecessary accompaniment in the learning process has certainly contributed to various educational practices, such as programmed instructions and individualized learning, which are geared to the elimination of failure experiences. Other practices, such as anecdotal reporting and social promotion, are also designed to shield students from the experience of failure and frustration. I shall therefore first discuss some of the adverse effects of a failure free environment before discussing some of the educational applications of the frustration-exploration hypothesis.

First, a failure free environment means the absence of challenge. McClelland (1969) has demonstrated that achievement-oriented people prefer moderately difficult tasks with a fair chance of failure. Berkowitz (1964) has made the same point that optimal challenge requires occasional frustration. It is difficult to think of situations where challenge exists without the possibility of failure. Secondly, the absence of failure also means the absence of true success. It is dubious whether one can experience the satisfaction of success in a task in which one could not possibly fail. There is evidence that people do not experience pride when they succeed in an easy task, and that the incentive value of success is inversely related to the probability of success

(Weiner & Kukla, 1970). Thirdly, the absence of failure means the absence of the needed stimulant to intellectual growth. According to Piaget (1966), some degree of discrepancy between existing schemata and environmental demands is essential for cognitive growth, although too great a discrepancy may create learning problems (Adelman, 1978).

In addition to the above adverse effect on achievement motivation and intellectual growth, a failure free environment fails to equip students with the necessary skills to cope with failure and frustration in real life. The consequences could be far reaching and serious, if students have not learned how to tolerate and cope with frustration constructively. For example, attrition rates would be high when these students move on to institutes of higher learning or the world of work where one is no longer protected from the harsh reality of competition and assessment. Their inability to cope with frustration might also make them vulnerable to mental disorder, since there is evidence that "proneness to mental disorder increases directly with anticipation of, or actual, failure to reach desired goals (i.e., frustration)" (Parker & Kleiner, 1966, p. 10). Lerner has pointed out that the "revolution of rising expectations" may touch off a "revolution of rising frustration" (Evinger, 1971). While education and mass media continue to raise expectations, economic realities make it increasingly difficult to fulfill these expectations, resulting in mounting frustrations. Inability to cope with these frustrations constructively may have serious social repercussions.

In view of the above considerations, it should have become apparent that the complete absence of failure could be just as harmful as too much failure, and the school has the responsibility of teaching students how to cope with failure and frustration. Unfortunately, the importance of teaching coping skills and the constructive role of frustration in the learning process have not received due attention from educators. On the basis of past research on frustration and exploration, I will venture some practical suggestions as to how one may apply the frustration-exploration principle to education.

D'Amato (1970) points out that schools must be geared to the "real" world where no one can exercise complete control over error responding, and suggests that an individual's frustration tolerance might be increased by gradually exposing him/her to an increasing amount of frustrative nonreward. There is evidence that such a gradual procedure increases tolerance of aversive situations (Miller, 1960; Peters, Wong, & Traupmann, 1971). We also have evidence that when the amount of frustrative nonreward is gradually increased as in the case of progressively increasing ratio requirements, animals become more resistant to extinction (McCuller, Wong, & Amsel, 1976; Wong & Amsel, 1976). One should take into consideration individual differences to ensure that the amount of frustration to be overcome should not exceed an individual's tolerance threshold, and there is an optimal amount of frustration which generates the strongest exploratory tendency. How much frustration one could tolerate depends on the amount of frustration one has successfully overcome in the past. Therefore, the procedure of gradually increasing the period or amount of frustrative nonreward builds up one's frustration tolerance, as long as such a procedure is not carried to the "breaking point". The experience of overcoming a very difficult task after prolonged frustration and many trials and errors could greatly increase one's sense of competence and achievement motivation. For example, Silber, Hamberg, Coelho, Murphy, Rosenberg, & Pearlin (1961) interviewed academically outstanding adolescents and found out that an important means whereby these students maintained a high sense of competence was by recalling the way in which they had successfully coped with difficult situations in the past.

Another procedure is to mete out failure occasionally. This may be accomplished by interspersing some difficult items in instructional materials or examination questions. As we have seen earlier, such a procedure not only makes the task more challenging, but also increases one's tendency to persist and explore in subsequent frustrating situations. The persistence effect of partial reinforcement training is well established in the animal literature (Robbins, 1971). We also have evidence that a mixture of success and failure increases persistence in the school setting (e.g., MacArthur, 1955). The optimal level of partial reinforcement in promoting persistence and exploration may depend on one's age as well as one's past reinforcement history. This procedure is especially useful in programmed instructions where the problem of maintaining students' interest and task persistence is exacerbated in the absence of an instructor.

Finally, the frustration-exploration principle can be readily applied by using the shaping procedure. Traditionally, this procedure has been used in behaviour modification programs, and typically the successive steps of approximation are made small enough to minimize frustration and failure. In contrast, I propose that this procedure be applied to all kinds of academic behaviours, and the successive steps should be sufficiently large to permit the operation of frustration induced exploration. For example, once a certain level of performance has been reached by the students, a higher level of performance should be required. This new level should be sufficiently difficult to attain so that the students have to put forth serious efforts to explore more efficient, more sophisticated, or more creative ways to perform the task. Once this new requirement is met, a still higher level of performance is instituted. By constantly stretching the students' "growing edge", this procedure may help to shape them into competent and creative individuals who know how to cope with frustration constructively.

Conclusions

It seems warranted to conclude that Berlyne's uncertainty-exploration principle can be extended to situations involving frustrative nonreward. The evidence supporting the frustration-exploration hypothesis is at this moment at least credible if not compelling. The generality of this hypothesis remains to be tested in different learning siutations, involving different species at different levels of development.

I have also marshalled evidences attesting to the beneficial effects of frustration-motivated exploration in learning, and proposed procedures of implementing the frustration-exploration principle in educational practices. Since the very nature of human existence involves frustration, we might as well learn how to turn it to our advantage by following the frustration-exploration principle.

RESUME

Le principe formulé par D.E. Berlyne exprimant que l'incertitude mène à l'exploration, s'applique à des situations non suivies de récompense frustrantes. Cette hypothèse de frustration-exploration est soutenue à la fois par des observations empiriques et des analyses logiques, qui posent que la frustration éprouvée devant l'incertain entraine l'exploration, dont le but primaire est d'élargir le rayon de selection de résponses. Cette exploration ainsi motivée peut faciliter l'apprentissage, Il en suit une documentation et une discussion sur les implications possibles de ce phénomène dans le domaine de l'éducation.

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