Order Number 8925242

Differences in problem representation and procedural knowledge between elite and non-elite springboard divers

Huber, Jeffrey Jay, Ph.D.

The University of Nebraska - Lincoln, 1989

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

DIFFERENCES IN PROBLEM REPRESENTATION AND PROCEDURAL KNOWLEDGE BETWEEN ELITE AND NON-ELITE SPRINGBOARD DIVERS

by

Jeffrey J. Huber

A DISSERTATION

Presented to the Faculty of

The Graduate College in the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Interdepartmental Area of Psychological & Cultural Studies

Under the Supervision of Professor Royce R. Ronning

Lincoln, Nebraska

May, 1989

TITLE

Differences in Problem Representation and Procedural Knowledge

Between Elite and Non-Elite Springboard Divers

BY

Jeffrey Jay Huber

APPROVED	DATE
Dr. Royce Ronning	
Dr. Roger Bruning	
Dr. Elizabeth Petrakis	
Dr. Steve Wise	
Dr. James O'Hanlon	
Dr. James Walter	

SUPERVISORY COMMITTEE

GRADUATE COLLEGE UNIVERSITY OF NEBRASKA

GRAD 82002 300 8-88(T)

DIFFERENCES IN PROBLEM REPRESENTATION AND PROCEDURAL KNOWLEDGE BETWEEN ELITE AND NON-ELITE SPRINGBOARD DIVERS

Jeffrey J. Huber, Ph.D.

University of Nebraska, 1989

Advisor: Royce R. Ronning

The study examined two areas relevant to cognition and motor performance: problem representation and procedural knowledge. Divers were asked to report their thoughts following dive performance. Their reports were then transcribed and converted into network representations and production rules.

Conversion results supported four hypotheses. The first hypothesis asserted that differences in problem representation between elite and non-elite divers would be consistent with differences between experts and novices in non-sport domains like mathematics and physics, as postulated by Chi and Glaser (1980).

The first postulate stated that elite divers would have more central concepts in memory relevant to the dive. No difference between the two groups of divers was apparent. The second postulate stated that elite divers would have more features defining each node. Non-elite divers cited 29% fewer features than elites. The third postulate stated that elite divers would have more relations interrelating nodes. Elite divers revealed 65 interrelations, while non-elite divers indicated only 10. The fourth postulate stated that elite divers would form more robust relations between concepts. The concepts reverse dive and reverse 2 1/2

activated higher order concepts 24 times for elites but only 5 times for non-elites. The fifth postulate was that elite divers would associate more procedural knowledge with each dive. Elites associated 105 production rules. Non-elites associated only 40.

The second hypothesis asserted that elite production rules would reflect a greater degree of learning in the areas of compilation and tuning. Results indicated that elite productions reflected greater proceduralization and composition--two subprocesses of compilation--and greater discrimination and strengthening--two mechanisms for tuning.

The third hypothesis asserted that elite divers would represent the problem of dive performance on a higher level than would non-elites. Non-elite representations generally consisted of "naive" elements, while elite representations consisted of higher order elements.

The fourth hypothesis asserted that elite divers would define the four problem components of a dive differently than would non-elites. Clear differences between the two groups were evident.

Table of Contents

CHAPTER ONE

INTRODUCTION AND STATEMENT OF PURPOSE

In the past, explanations of differences between experts and non-experts were characterized by elusive words such as "intuition" and "talent." These words are reminiscent of the days of behaviorism when the mind was seen as some impenetrable box unavailable for true scientific study and unnecessary for explaining differences in human behavior.

Only recently have researchers begun to understand what experts do differently from non-experts to account for superior expert performance (Larkin, McDermott, Simon & Simon, 1980). With the advent of information processing theory and the computer, researchers have new theoretical models and new metaphors for understanding and accounting for differences in human behavior on a cognitive level.

The study of expertise often involves examining differences in problem solving performance between experts and novices. Performance usually is examined by asking subjects to recall structured and unstructured information; by asking subjects to think aloud as they solve problems; or by asking subjects to write down each step as they work through a problem. Some sort of protocol analysis then follows. Chi and Glaser (1980) believe that examining

differences between experts and novices is a fruitful way of developing a cognitive theory that will provide new advances in techniques for instructing and assessing advanced levels of achievement.

Using an expert-novice paradigm, previous research has found qualitative differences in cognition between experts and novices in chess, bridge, physics, reading, mathematics, and other problem solving domains. These differences suggest that experts manipulate, organize, store, and retrieve information in ways consistently different from those of novices. Are there similar cognitive differences between elite and non-elite athletes?

Starkes and Deakin (1984) suggest that differences between skilled and novice athletes can be routinely demonstrated on a cognitive dimension as well as a physical/motor dimension. They believe a "software" approach asking questions concerning the cognitive component of skill is more fruitful for determining differences between athletes than a "hardware" approach that typically looks at such factors as reaction time and depth perception.

For the past twelve years, the writer has had the opportunity to coach all levels of diving, from the beginner to the national finalist. During this time some divers who appeared to possess good physical talent never reached their potential, even though they seemed highly motivated and

diligent. In contrast to elite divers, these non-elite divers typically were slow to learn from their mistakes and had trouble putting together "all the pieces" of a dive.

Why is it these divers did not become elite level performers, even though they had high vertical jumps and quick reaction times? A hardware approach does not seem to explain this observable lack of development. Consequently, the initial impetus for the current study was the writer's desire to better understand from a software approach why some athletes fail to live up to their physical potential and how these athletes might be helped.

STATEMENT OF PURPOSE

One problem with past research examining differences between elite and non-elite athletes is that it has often completely ignored a very important part of performance--human cognition. Earlier research tended to look strictly at physical attributes. Yet, as a study by Starkes (1987) suggests, cognitive attributes can be much better at differentiating between elite and non-elite athletes than physical attributes.

The purpose of the current study was to examine the possibility that differences between elite and non-elite divers can at least in part be explained by differences in cognition--the software component of performance. More

specifically, this study examined two areas relevant to cognition and motor performance: problem representation and procedural knowledge.

To get at these differences, elite and non-elite divers were asked to report their thoughts immediately after dive performance. Their verbal reports were then transcribed and converted into network representations and production rules.

The network representation for each dive were formed by taking all nouns and action statements and associating them with each other as indicated from the respective protocols. Newell and Simon (1972) suggest that the problem representation can be defined directly in terms of the internal symbol or knowledge structure. This study assumed the converted networks to be gross representations of the divers' internal structures. The theoretical validity for making such an assumption is discussed in greater detail in Chapter 4.

According to Anderson (1983), knowledge about how to perform a task can be represented in the form of production rules. Productions are rules that contain condition and action clauses. The production rules for each diver in this study were formed by identifying all statements within each protocol that could be interpreted as reflecting an "if-then" structure. The theoretical validity for examining production rules is discussed in detail in Chapter 3.

The main purpose of this study is to examine four hypotheses. The first hypothesis is that differences in knowledge, or problem representation, between elite and non-elite divers is consistent with differences found between experts and novices in non-sport domains. Chi and Glaser (1980) have postulated five differences in knowledge, or problem representation, between experts and novices and it is hypothesized that these five differences are evident between elite and non-elite divers.

The first postulate of Chi and Glaser is that experts have more central concepts in memory that are relevant to their subject of expertise. The second postulate is that more relations, or features, define each node for experts than novices. The third postulate is that experts have more relations interrelating the nodes. The fourth postulate is that experts have more robust relations between concepts, which means that the probability is greater that a concept will evoke other concepts as well as evoking its defining features. Finally, the fifth postulate is that experts associate more procedural knowledge with a problem and that this knowledge is more discriminating for experts than for novices.

Anderson's (1983) ACT theory outlines two mechanisms--compilation and tuning--that account for learning within a production rule framework. A second hypothesis of this

study, then, is that elite divers not only have more production rules (procedural knowledge) associated with a dive but also have higher quality production rules. In other words, it is hypothesized that elite production rules reflect a greater degree of procedural learning than non-elite production rules. The two areas of production rule learning this study specifically examined are compilation and tuning. The theoretical basis for making this second hypothesis, as well as a detailed explanation of ACT theory, is provided in Chapter 3.

A third hypothesis of this study is that elite and non-elite divers differ in their level of problem representation. In other words, elite divers represent the problem of doing a good dive on an idealized level whereas non-elite divers represent the problem on a literal level. Again, this is a somewhat consistent difference between expert and novice problem solvers in non-sport domains, particularly physics (McDermott & Larkin, 1978).

According to Glass and Holyoak (1986), all problems have four components: goals, objects, actions (operations), and constraints. A software approach to examining differences in performance allows performance to be considered as a form of problem solving. The fourth and final hypothesis of the study, then, is that elite divers

define the four components of the problem differently than do non-elite divers.

Differences in problem components are discussed by examining obvious differences in network representations and production rules between the two groups of subjects. These differences help the study achieve another purpose: to better understand how elite divers perceive the problem of performing a great dive and to suggest ways of applying this knowledge in a coaching situation to improve performance.

The following three chapters provide theoretical support for the hypotheses and assumptions stated in this section. Chapter 2 outlines Schmidt's (1975, 1982) schema theory, which is the first full-blown motor development theory that accounts for the role of cognition in physical performance and supports the notion of a software analysis of differences between elite and non-elite divers. Chapter 3 outlines Anderson's ACT theory and explains the notion of production rules and how they are well suited for representing procedural knowledge and procedural learning. Finally, Chapter 4 discusses Newell and Simon's (1972) information processing based theory of human problem solving and explains how the symbol structure, or network representation, can be considered the problem representation.

CHAPTER TWO

REVIEW OF MOTOR LEARNING THEORIES

A "software" approach to explaining differences in athletic performance is supported by both theory and research. Prior to the review of related research, the two main theories in the area of motor learning will be discussed.

While there are many hypotheses concerning motor movement, only two fully developed theories deal exclusively with motor learning: Adams' Closed Loop Theory and Schmidt's Schema Theory. Since Schmidt's theory was formulated in reaction to some shortcomings in Adams' theory, Adams' theory will be discussed first.

ADAMS' CLOSED LOOP THEORY

Adams (1971) postulated the existence of two traces in memory: a memory trace and a perceptual trace. The memory trace is a modest motor program and its function is to choose and initiate an action. The perceptual trace is a reference of correctness within the central nervous system. The perceptual trace is developed through practice and knowledge of results (KR). Once formed, the reference of correctness is compared with proprioceptive feedback in an ongoing closed-loop feedback system.

Adams believed all movements are made by comparing the ongoing feedback from the limbs during the motion to the reference of correctness, which is learned from practice. During positioning responses, where the individual must learn to locate the limb at a proper position in space, the perceptual trace represents the qualities of the correct position. By minimizing the difference between the feedback from the actual movement and the perceptual trace, the limb is brought to the correct position by a closed loop control process.

Predictions and Supporting Evidence

Based on his theory, Adams made several predictions concerning KR that appear to be supported by research. Adams (1971) argued that (a) lengthening the KR-delay interval should have no effects on learning, (b) shortening the post-KR delay interval should have negative effects on learning, and (c) lengthening the inter-trial interval too much should have negative effects on learning. These predictions, plus additional predictions about the precision and withdrawal of KR, seem reasonably well supported in the research literature on KR without contradictory findings (Schmidt, 1982).

Feedback from the limbs, according to Adams' theory, is important for developing the perceptual trace. Therefore,

Adams argued (1971) that factors increasing such feedback should enhance learning and factors degrading or eliminating such feedback should retard learning. In a series of experiments using positioning tasks, Adams and his colleagues showed these predictions to be well supported (Adams & Goetz, 1973).

Limitations and Contradictory Evidence

Although it makes some accurate predictions, there are several problems with Adams' theory. As Schmidt (1982) points out, there is a logical inconsistency in Adams' theory. Adams has the perceptual trace placing the limb at the target (the correct response) **and** knowing how far away the limb is from the target. If the trace is suppose to correctly position the limb, how can it simultaneously know the error factor?

A second problem with Adams' theory is its limitation in scope. While the theory has potential applicability to slower responses, most researchers agree it is not applicable to all motor learning, particularly rapid movements. Rapid movements require the motor program to be selected and initiated before the movement and they allow very little, if any, time for the use of feedback during the movement. In general, a number of Adams' predictions

concerning rapid movements do not hold in laboratory research (Schmidt, 1982).

A third problem with Adams' theory has to do with contradictory evidence from research dealing with deafferentation. For example, animals and humans deprived of all sensory feedback from the limbs can respond skillfully and can even learn new actions (Taub & Berman, 1968). According to Adams' theory, this should not be possible, since sensory feedback is necessary for establishing a perceptual trace and placing a limb at a correct position by comparing the feedback to the perceptual trace.

Like all theories, Adams' theory is in one sense a product of its time. During the late 60's and early 70's, behaviorism was still influential and its impact was reflected in the emphasis on associationism and the de-emphasis on inner mental processes in Adams' theory. For this reason, Adams' theory is susceptible to some of the same criticisms as behaviorism.

In the area of language acquisition, behaviorism has been attacked by using some simple arguments. For example, language cannot be learned in a word-for-word, chaining process as suggested by many behaviorists. Chomsky and Miller (1958) estimated that a speaker of the English language can understand and produce more sentences than

there are seconds in a lifetime; such a feat is logically impossible from a behavioral perspective and indicates that these sentences cannot be learned individually. Rather, they must be generated from a set of rules, which is precisely how schema theory suggests motor movements are generated.

A second problem with a behavioral explanation of language acquisition is explaining how new sentences are generated. If language is acquired word-for-word, how can speakers suddenly generate sentences they have never seen or heard before?

Both of the preceding arguments against behaviorism's explanation of language acquisition can be leveled against Adams' motor learning theory. According to Adams' theory, each movement has its own perceptual trace that must be individually learned through practice. There are, potentially, so many different movements that it seems impossible for humans to have the time to learn each movement and the capacity to store a separate trace in memory for each movement. Further, Adams' theory does not explain how a novel movement can be suddenly generated. A rule based theory like Schmidt's can explain such a phenomenon.

In general, Adams' theory gives little importance to the role of cognition, particularly higher-order, executive

control, in the learning of motor movement. In response to these limitations, Schmidt (1975) developed his schema theory.

SCHMIDT'S SCHEMA THEORY

The concept of a schema was first introduced by Head (1926) and later popularized by Bartlett (1932). Schema is the term used for the abstract memorial representations for events, stories, skilled actions, etc., where the representation can be thought of as a concept, generalization, or rule about the event but lacking in many of the actual details (Schmidt, 1982). The term has been extended to the area of motor learning where Schmidt argues that a motor response schema controls movement.

An important characteristic of a schema is that it is developed by abstracting pieces of information from related experiences and combining them into an organized knowledge structure. In Schmidt's schema theory, four pieces of information are stored when an individual makes a movement that attempts to satisfy some goal.

The first is information concerning the **initial conditions** related to the response. The initial conditions consist of the information received from the various receptors prior to the response, such as proprioceptive information about the positions of the limbs and body in

space, as well as visual and auditory information about the state of the environment. After the movement, the initial conditions used to plan the movement are stored.

The second piece of information stored is **response specifications.** Since a motor program is assumed to be rather general, elements like speed and force must be specified before the movement can be run off. After the movement, these specifications are stored along with the other information received after the movement. These serve as a record of the specifications of the movement produced.

The third piece of information stored after the movement is the response-produced **sensory consequences.** This information consists of the actual feedback stimuli received from the eyes, ears, and proprioceptors. The sensory consequences are an exact copy of the afferent information provided on the response.

The final source of information stored after the movement is the **response outcome.** The response outcome is the actual outcome of the movement in contrast to the originally intended outcome. Outcome information arises from information the subject receives after the movement and consists of knowledge of results (KR), when present, and subjective reinforcement.

In the beginning of skill acquisition, a number of gross attempts to approximate the correct move are made.