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CHESS AND COGNITIVE DEVELOPMENT

An Experimental Psychological Study in Youths at the End of the Primary School Period

Thesis submitted for obtaining the degree of Licentiate in Psychological and Pedagogic Sciences in the Area of Developmental Psychology

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CHESS AND COGNITIVE DEVELOPMENT

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EDITOR'S PREFACE

"Learning chess makes youngsters smarter in the classroom."

This is the 'surprising' finding of a two year (1975-76) experiment in Belgium by Johan Christiaen, Gent National University, Faculty of Psychology and Pedagogic Science.

He taught an experimental group of twenty boys (average age 10½ years) an elementary chess course totalling 42 hours of after school chess sessions over a two year period in a municipal school. There was a control group of like number and grade (initially grade 5, later grade 6).

There was a significant difference between the two groups in scholastic results in favor of the chess group.

Johan Christiaen: "Considered generally, the rather great positive influence of chess on school results in both the fifth and sixth school year seems rather unexpected ....."

Why perhaps unexpected?

The primary purpose of the experiment was centered on the cognitive development theories of Jean Piaget (died in Geneva on 16 September, 1980, age 84): "Can an enriched environment (chess playing) accelerate the transition from the concrete level (stage 3) to the formal level (stage 4)?"

The scholastic achievements were thus incidental to the aim of the experiment.

Adriaan D. de Groot, noted introspective psychologist, in his 10 page memorandum (Dec.1977) "Chess Instruction In School?" ranks the Belgium Study as the best experiment he has seen in educational research concerned with the differential effects of chess instruction on the mental development of school children:

"...The mastery of the rules (of chess) .... mastery of standard mating procedures ..., and knowing something about a few opening systems ... are easily defined knowledge objectives that are attainable by almost all pupils. In addition, the Belgium study appears to demonstrate that the treatment of the elementary, clearcut and playful subject matter can have a positive effect on motivation and school achievement generally ...."

H.L.

"Chess and Cognitive Development" is a major component of the copyright (1981) package "Chess in the Classroom: An Answer to NIE" and is identified therein as Part I, Item F.

AUTHOR'S INTRODUCTION TO ENGLISH LANGUAGE EDITION

(Flemish translation)

Following the request of author Harry Lyman for a brief introduction to this English-language edition of my study relating to "Chess and Cognitive Development," I can begin by offering my best thanks for the interest he has shown in my work.

In spite of the fact that the study took place five years ago, I am still convinced of the usefulness of chess instruction in schools, for example.

If it were not for time pressures and financial impossibility, I would have already long ago continued to develop the investigative results further in a number of areas which were pointed out to me by Prof. Dr. De Groot, among others.

Now that years have passed since the thesis appeared, there has been some reaction developing to it im my own country and others. Publications are underway in various journals, and hopefully we will soon fond confirmation of the results by related studies. There are indeed a considerable number of possibilities still available to interested investigators on the potentials of further analyses or follow-ups, and indeed a new investigations should be set up on the basis of this thesis and the reactions which have appeared since then, spread over a longer time, since a follow-up study could also be made after a period of time. A dream of Harry Lyman's might perhaps come true in the near future....

AUTHOR'S PREFACE

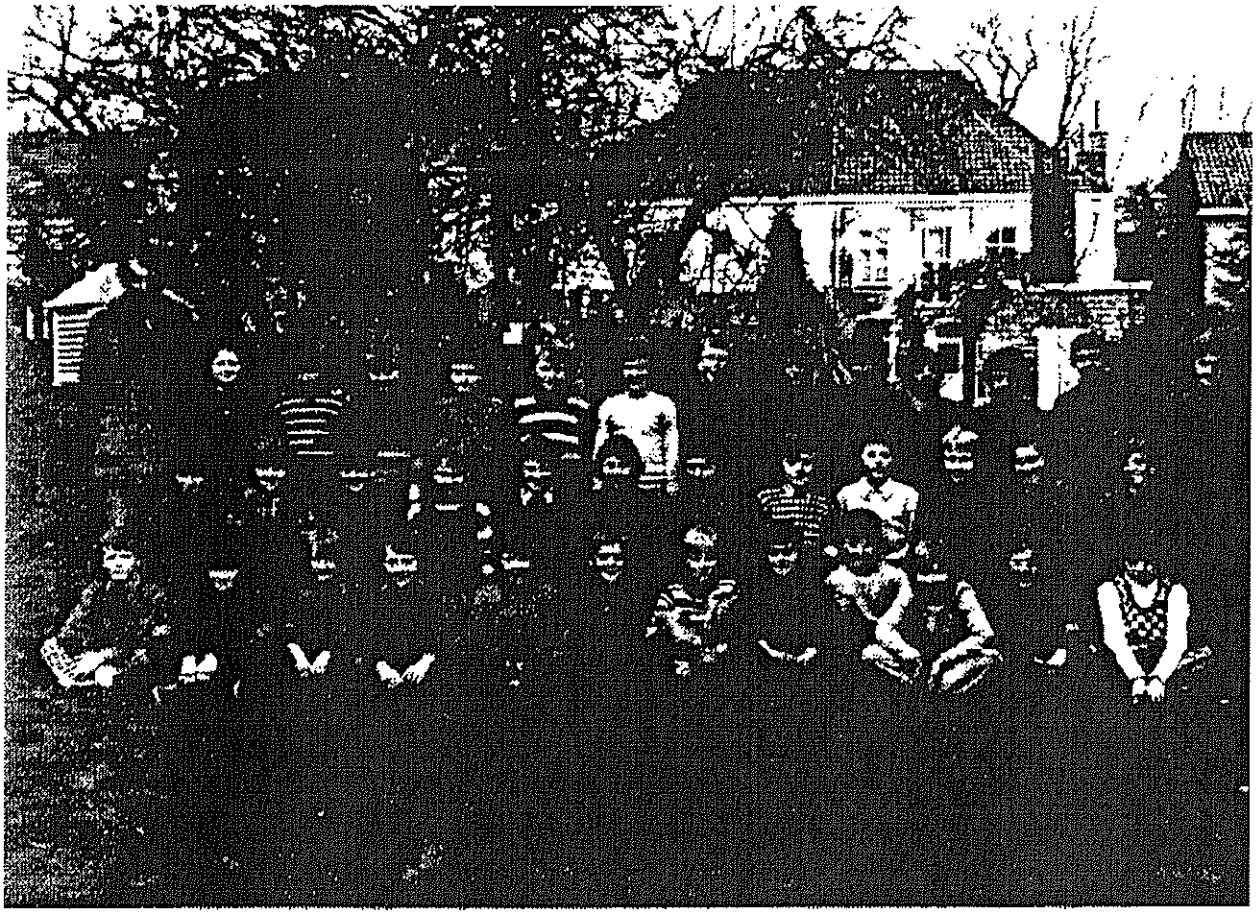
In the submission of this thesis for receiving the licentiate degree, we wish to express our thanks to all the teachers and professors of the Faculty of Psychologic and Pedagogic Sciences at the Gent National University for the scientific and psycho-pedagogic training we received from them.

In particular, we want to thank Prof. Dr. L. Verhofstadt for assuming responsibility for the promotion of this thesis and for her assistance, encouragement, and suggestions, which provided a great deal of support for us.

We also want to thank the directors and the teachers R. de Lust and R. Dierickx of the Assenede Municipal School for their permission and assistance in giving the weekly chess lessons. We thank International Chessmaster Bernard De Bruycker and National Youth Leader Roger Van den Berghe for supplementary literature data relating to chess. We also extend our appreciation to the Service for Studies and Occupational Orientation of Eeklo and to Liliane Christiaen for their indispensable assistance in the execution of the intelligence and cognitive tests. We thank I. Mervielde for his help and recommendations in the statistical processing of the results.

Last but not least, we are also indebted to all the students from the fifth and sixth grades of the Assenede Municipal School who made the experiment possible through their weekly attendance.

Gent, July 1976



TEACHER AND PUPILS OF ONE OF THE TWO CLASSROOMS IN THE BELGIUM EXPERIMENT.

(SEE PP 22-26 OF TEXT)

INTRODUCTION AND PROVISIONAL PRESENTATION OF PROBLEMS

Particularly in chess circles, but also outside them, a relationship is not infrequently claimed between strong chess-playing ability and good scholastic results, for example. The opinion is sometimes also expressed that factors such as concentration, analysis of problems, memory, and the like can come into play in chess and presumably are further developed as a result.

A number of these (untested) statements have contributed to the introduction of chess instruction (outside of class time in Belgium, it is true) in certain primary and secondary schools.

A study on the precise contributions of chess instruction in the development of cognitive structures and school results as well as other intelligence tests seemed to be urgently necessary.

In our study, we were particularly concerned with the influence of chess on the course of cognitive development as described by Jean Piaget. A possible influence on school results and on the results of a couple of intelligence tests were also to be investigated.

Whereas we will briefly say something on chess, chess instruction, and the already published psychological studies relating to chess in the first part of this thesis, the basic principles and phase classification in Piaget's cognitive theory will be discussed further in the second part.

An experimental investigation in which 2 groups of students, an experimental group and a control group, are to be compared, will provide the basis for a number of conclusions on chess and cognitive development which we will deal with in the third part.

PART 1: CHESS

"Research is what gives me pleasure. Research and discovery in the sciences are analogous to the game of chess."

Nobel Prize-Winner in Physics 1970
Prof. Dr. Néel, Grenoble 1973

I. CHESS

A. History and description

Chess developed in Asia, probably in India, in the sixth century and was later brought to Europe by Islam between 700 and 900, where it was initially introduced into Spain (Murray 1913).

Only from the 13th century did the game also become known in our areas, but here, too, it remained a pastime for "nobles" for centuries. It was at the beginning of that century that chess also gradually became known to the "broader" strata of the population.

The International Chess Federation, established on July 20, 1924 (known as FIDE) at Paris, contributed a great deal from the time of its establishment to make the playing rules uniform over the entire world. As a result of this uniformity of playing rules, it became possible to conduct large international tournaments which in their turn contributed to the dissemination of chess.

The question of precisely what chess is and precisely how it is played remains to be discussed. In contrast to textbooks on chess, most encyclopedias still always present descrptions of chess in the sense of: "A board game resembling war played by 2 players on a square board provided equally with chess pieces, the board being divided into 64 alternately light and dark-colored square fields of equal size." (Grote Winkler Prins 1973). In other words, chess is thereby always still compared with a battle between 2 "armies" led by a king ("shah" in Persian).

B. Different types of chess

It is impossible to be complete in this section. We attempt only to clarify a number of terms which will later be mentioned.

1. Usual chess

This term is used to indicate what the layman usually understands to be chess.

There are 2 players in the usual chess, a white player and a black player, according to the color of the pieces they play with. They each make one move in turn on one board and have "all" the necessary time to consider for that purpose.

This usual slow chess is played with the use of a chess clock in competitions which is so regulated that, for example, it is necessary to play a minimum of 50 moves in 2½ hours and after that for example 20 moves per hour. This time allotment for a game may vary according to the tournament.

2. Rapid-transit chess

The so-called "blitz" chess is a short game between 2 players with a maximum time for considering of 5 or 6 minutes per player.

3. Simultaneous chess

In this case, a white player undertakes to play against several black players on different boards. The white player goes from board to board and makes one move on each board, after which the black player considers his reply, which he makes on the following arrival of the white player. Time is not taken into consideration, unless a session with clocks is involved.

According to the strength of the players, the white player can play against 10 to 50 black players.

4. Chess without sight of the board

A form of chess in which neither board nor pieces are used. Each player gives his move orally and writes down the moves as in the case of a usual chess game. It is also possible to play this blindfold chess simultaneously. Hungarian International Master J.L. Flesch thus played a simultaneous blindfold match in 1960 in Budapest against 52 top players, in which he won 31 games, lost 3, and had 18 draws. The session lasted around 12 hours.

This form of chess was the first to draw the attention of psychologists to chess (Binet 1893).

5. Correspondence chess

This chessplaying by mail is popular among strong players as it thereby becomes possible for chessplayers from all parts of the world to play. This form is led by the World Correspondence Chess Federation.

The most important difference in comparison with other sorts of chess is that in correspondence chess the players are able to study all chess books and analyses before making their next move.

6. Computer chess

Pioneer work has particularly been done in this field at Moscow University (Euwe 1963).

In the first computer chess championship held at Stockholm in 1974, Russia won with a program taking into consideration opening theories from not less than 10,000 books (Finnish Chess Problem Association 1974). (1)

(1) A chessgame is divided into opening, middle game, and endgame. A large number of opening theories already exist on how to open a game.

Former world champion M.M. Botvinnik worked for years on a complete mathematical representation of chess (Brown 1970).

Due to the great advances made in the computer field during recent years, Prof. Dr. A De Groot expressed the opinion:

"It is indeed possible to develop a machine which can perform more operations than a person, but it is not yet possible to get a computer to play better than a person. This is because a computer does not have any intuition. A machine is good at calculating but poor in evaluating. I am unable to calculate all variations. I must stop somewhere and make an evaluation. It is precisely at this point that the chessplayer wins over the machine." (PAM 1975, pp. 35-36).

C. Study of chess in Belgium

The KBSB (Royal Belgian Chess Federation), the main chess organization in Belgium, was founded in 1920. On Jan. 1, 1976, the KBSB had 122 associated chess clubs with a total membership of about 4,500 players, 1500 of them youthful players, this category including those less than 20 years old.

During the last 5 years, the predominance shifted both quantitatively and qualitatively from Wallonia to Flanders, where particularly the number of youthful players increased rapidly.

In addition to the above mentioned competition chessplayers, a group which cannot be estimated is concerned with chess as a sporadic pastime to be played now and then.

In comparison with most other countries, Belgium occupies a low-level position with respect to the number of players and playing strength (only one international master (1). Due to a more efficient campaign for youth chess, however, an advance has been made in recent years, especially qualitatively.

Chess was recognized in 1975 by the Ministry of National Pedagogy and Culture, which represented a great step forward, especially with respect to financial problems.

D. Study of chess in other countries

Introduction

We here briefly discuss only Russia, because of its quantitative and qualitative predominance over the entire world, and Holland, due to its great influence on Belgium. Considered according to playing strength, Russia is followed by most other eastern-bloc countries, followed by Cuba, the USA, and West Germany.

1. USSR

Russia has remained the leading country in the field of chess since the second world war. There were 150,000 officially registered players in 1929, and in 1966 the number had increased to 3,540,000.

(1) International master: A title granted by FIDE in recognition of good results in important international tournaments.

In addition, there are also millions of noncompetitive chessplayers (Sunnucks 1970). "Chess sections exist in every factory or works organization in the country, in every Pioneer Palace and almost every college and school." (Sunnucks 1970, p. 515).

A department was set up at the University of Moscow in 1968 specializing in the study and teaching of chess (Frank 1972).

2. Holland

Especially on account of Prof. Dr. Max Euwe, chess has gained great popularity in Holland. When Dr. Euwe became world champion in 1935, there was a great increase in the number of competitive chessplayers in one year's time from 3,000 to more than 11,000 (PAM 1975, p. 171). Due to their tens of books on chess and chess theory, Prof. Dr. A. De Groot and H. Bouwmeester also contributed to increasing the popularity of chess in Holland.

Holland occupies a rather high position not only quantitatively (about 20,000 competitive chessplayers in 1975) but also qualitatively (2 international grandmasters and 10 international masters)

II. CHESS INSTRUCTION

A. Features

1. Place

Whearas earlier chess was usually "accidentally" learned at a friend's house, more consideration is given nowadays in written articles and discussions to obtaining more thinking persons for chess. Once interest has been aroused, the next step is frequently to go to a club, where further instruction is usually limited to obtaining experience in competitions.

In recent years, schools have also become a prominent medium for the teaching of the rules of chess. Whereas this originally began with a game of chess during the noon hour between a couple of students who already knew chess, chess activities gradually grew into a form of instruction by a teacher, himself usually a dedicated chessplayer, to all interested persons. Such instruction is given both during noon hour and after the end of the normal class program.

2. Pupils

a. Selection

As has already been shown, this form is limited to students who are interested in such instruction. There is no obligation to attend lessons, so that uninterested students automatically do not participate. This uninterested group includes strikingly more students with poor than with good school grades.

b. Age

According to Prof. Dr. Laroslaw Koch of the Pediatric Institute of Prague University, a child 4 to 6 years old can correctly learn the first chess moves.

In Psychology and Chess, Agustin Puig writes that the ideal age for learning chess is around 7 years old (Puig 1971).

Chess instruction has been given in our country in a number of secondary schools for the last 2 years. Only last year, chess lessons were begun at the end of elementary school in 5 places (Dendermonde, Grimbergen, Brussels, Antwerp, and Eeklo).

c. Sex

The quantitative and qualitative participation of boys and girls in many sports, including chess, is quite considerable.

With respect to differences in strength between men and women, Prof. Dr. A. De Groot has the following to say: "On average, women have less aptitude for chess than men. This does not mean that there are no women with considerable aptitude, but only that their average is smaller." (PAM, 1975, p. 38).

3. Teachers

It was found right at the outset that teachers interested in chess exist in Flanders capable of organizing chess lessons in the various schools in which they themselves are teaching. Very often, their chess clubs considered chess instruction in school primarily as a source of material capable of being enrolled in the club after a couple of years as youthful chessplayers of "champion format."

It is not surprising that many of them began teaching at the beginning (and still do so) incompletely prepared for such instruction. It was characteristic, for example, that after half a year of teaching, on average, only half the students were still continuing the first lessons. Since, however, the intention was only that of retaining the best future competitive chessplayers, that fact was considered unimportant or "normal."

The first organized chess lessons were given in secondary schools in Belgium at around 1972 and in elementary schools at around 1974, which had already been begun in Holland 2 years earlier (especially under the influence of the already mentioned "Mammoth" Act).

It is therefore not surprising that a shortage in recognized and competent teachers was felt last year among our northern neighbors (in Holland: Translator). In March 1973, KNSB (Royal Dutch Chess Federation) issued an "Instruction Book for Youth Chess" in which C.J. Overbeeke, chess instructor of the KNSB, gave some practical

hints on giving chess lessons to youths between 9 and 14 years old in a couple of pages. However, this was limited to and based upon the method presented in the book Jeugdschaak (Chess for Youths) by B. Withuis.

A further stage in the training of chess instructors appeared in November 1975 at Roosendaal. The KNSB organized 12 lesson series at Roosendall, concluded with an examination by a central examination board. After this first theoretical part, a year of practice followed, after which an examination was to be taken.

B. Methods

1. Jeugdschaak (Chess for youths) - B. Withuis

This illustrated book, written by chess journalist Berry Withuis, has been the textbook most used in both Holland and Flanders for teaching chess at the end of elementary school and also in secondary schools.

The book contains 3 large sections, each concluded by an examination, for which the KNSB respectively gives a pawn, rook, and king diploma. The 3 sections, conforming to lessons for beginners, advanced and better players, are further subdivided into a number of chapters adapted to the teaching which can be given in one hour of theoretical presentation. A number of practical applications are provided after each chapter.

The easy-to-understand text, the alternation of text and problems, and the favorable price are the outstanding advantages offered by this book in comparison with other chess instruction books. Typically Dutch illustrations and expressions of Dutch chess life are less directed to Flemish children, however.

2. Chess lessons - R. Fischer

This book is a programmed course for beginners and advanced players. The former world champion did not so much intend to present chess lessons for youths in this book as for anyone, including adults, who wanted to learn chess (1). From this standpoint, he presents only a succinct and quite general description of the playing rules, after which a number of openings follow in the second section with the aid of diagrams.

The difference between these chess lessons and the foregoing instruction method is illustrated with the aid of the following example on the possible moves of a pawn:

Withuis, 1975, p. 31: "The pawn is the supporting character in chess, but don't forget him. He is indeed small, and he is not too valuable, but he has 7 brothers. He can sometimes make the greatest noise and suddenly become important.

(1) This relates to a linear program. (See De Block, 1968, pp. 41-48; 58 for meaning, advantages, and disadvantages.)

The strange thing about a pawn is that he does not capture in the same way as he moves. The pawn moves straight forward, but he captures obliquely forward. The pawn is the only chess piece which cannot move backward. We would like to say something more about him.

Each first move of a pawn, thus of all 16 pawns (the 8 white and the 8 black pawns) can amount to a surprise. You may choose among 1 square forward or 2 squares forward. After his first move, however, a pawn may move only 1 square forward or capture on 1 square obliquely in front of him."

"Have you gotten a good understanding that a pawn looks at one square obliquely forward to the left and right and thus can also capture there? He does not look straight ahead; he only moves in that direction."

Fischer, p. 9: "The pawn moves in one direction and captures in another direction. This is not the case for other pieces. The pawn can only move forward but not backward. And only one square. With one exception: on moving from his square in the initial position, he has a choice between one or two squares forward. Thus only in the first move of each pawn."

A second important difference is to be noted in the sequence for learning playing rules.

Withuis begins with the playing rules relating to king and queen and after that already describes the concepts of mate and stalemate.

On the other hand, Fischer first describes the moves of all pieces, king, queen, rook, bishop, knight, and pawn, and only after that does he explain what check, checkmate, and stalemate mean. Fischer thus already loses the advantage in the first lesson of being able to introduce a number of exercises in chess . The chess student thus does not immediately know what the purpose of the game is, and he cannot derive"pleasure" from the first lesson in being able to give check, which can have a stimulating effect on children.

3. Other methods

Most other chess textbooks in Dutch can be considered inadequate for instructing children, for the following reasons:

1. no exercises or too few following the introduction of new concepts;
2. too late explanation of what check, checkmate, and stalemate mean (Panov 1960);
3. no division by chess lesson (Panov 1960).

III. PSYCHOLOGICAL STUDIES ON CHESS

A. Survey of current literature

De Groot wrote in 1946: "Although many more books have been written about chess than is usually suspected by the public or this field, the psychological side of the game has still remained a largely undeveloped area. The chess literature is for the most part purely technically oriented; it deals with the game and not with the player and his way of thinking, it deals with the problem but not with the problemist. Even the biographies of the leading personalities mostly deal with the games played by them, not much more than a recording of tournament results and prizes won and an evaluation of their chess career. Only scanty indications are found on their internal development, nothing or hardly anything is said of their character, and the question of how their achievements came about and what their expertise is based on has scarcely been dealt with."(De Groot 1946², p. 1).

The above assessment still holds true to a great extent 30 years later. In spite of the many statements that the psychological aspect is quite important in chess, to date only few scientifically based studies have appeared on the subject.

The Cleveland Public Library contains more than 100,000 books* on chess, about two-thirds of them dealing with opening theory and middle and endgame. Most of the publications come from the eastern-bloc countries, especially from Russia.

No figures are available on the number of works on chess in connection with psychology.

The current literature on the subject can be divided into 3 classes by the approximation method:
1. Studies on mental capacities necessary for the study of chess.
2. Studies on players considered from a psychological standpoint.
3. Studies on chess learning as being a "game" associated with complex thought processes.

With respect to the first category, Alfred Binet was the first to objectively investigate the different mental capacities of a good chessplayer (Binet 1894). He was interested in the extent to which a good memory contributed in a blind simultaneous exhibition (see above for meaning of the term). By means of interviews and tests given to the strongest chessplayers of the time, he came to the conclusion that the ability to play blindfold chess was based on 3 fundamental conditions:
1. knowledge and experience in the field of chess ("erudition")
2. imaginative faculty
3. memory.

The Russian professors Dyakov, Rudik, and Petrovskii subjected 8 grandmasters to psychotechnical tests in 1925 on the occasion of the great master tournament in Moscow.

* PDF transcriber's note: This figure is incorrect. The Cleveland collection consists of about 10,000 books. There may be as many as 45,000 distinct chess titles in the world as of the date of this transcription - April 2004 - KH

Their (debatable) conclusion was that chessmasters were more talented especially with respect to memory (Djakov, Rudik and Petrovskii 1927).

A similar conclusion was reached in a study made of Reshevsky, a prodigy who gave a 20-board simultaneous exhibition at age 8. Reshevsky was only found to be superior with respect to his age grades in a memory test in which he memorized a design of 28 numerals in 3 minutes (Baumgarten 1930).

In psychological studies in connection with the second category (studies on chessplayers considered from a psychological standpoint), a number of articles and books have appeared relating to the psychology of chessplayers from a psychoanalytical standpoint (Fleming, Strong 1943). Ernest Jones saw the problem of Paul Morphy's mental disturbance in the light of an inability to suppress his Edipus complex by chessplaying (also see Cockburn 1974 and Jones 1931). He generalized this position, later stating that chessplaying quite considerably possesses the father component of the Edipus complex. Reuben Fine was of the opinion that a suppressed homosexuality was probably the cause of Morphy's disease, a cause he also found in other chessmasters (Fine 1967). Donner also believed that a significant connection existed between chessplaying and homosexuality (PAM, 1975, p. 52).

Barendregt is not in agreement with such opinions: "There are actually very few homosexuals among chessplayers. I can indeed state that they do not require physical homosexuality because this is satisfied in the state of 2 men at a chessboard, but I would like to dismiss all such assertions. . This is cafe psychology." (PAM, 1975, p. 100).

Frank makes the following statement concerning pathology and chess: "The detractors of chess will find their major argument from a medical standpoint. Before 1948, all the world champions (except for Dr. Max Euwe) died mentally deranged." (Frank 1972)(1)

In addition, a number of books have appeared dealing with the playing style of certain masters. The many communications on positional play and combinative play belong in this category.

Little literature data is available relating to the third category , except for the studies and experiments in connection with computer chess already mentioned earlier. The discussion of a number of works by Prof. Dr. A. De Groot presented below represents one of the few communications with a scientific basis.

B. Thinking by chessplayers

Dutch Prof. Dr. A. De Groot was the first person, in 1946, to publish a first investigation conducted along strictly scientific lines under the above mentioned title.

In Het denken van den Schaker, De Groot attempts to show that the thought process to a great extent depends on prior experience.

(1) Editor's Note: This purported assertion by Frank is easily refuted.

What we call intuition in chess (and in thought) is, according to De Groot, "the activity of experience in a narrower sense." Chess mastery for him is chiefly expertise in the field of chess, i.e., an explanation of the particular achievements of a chessmaster is not so much to be sought in all kinds of abilities (combinative ability, imaginative faculty, etc.) but in a process proceeding from progressive development and at the same time a differentiation and improvement of the system of knowledge and experience of thinking and playing methods. (De Groot 1946, p. 277).

In one of his experiments, De Groot presented a position from an actually played game to trial subjects, chessmasters and less good chessplayers, and required them to seek a move in continuation of the game. During this simulation, De Groot had his trial subjects think aloud, and he drew up his standardized protocols on the basis of what the "pseudoplayers" said. On the basis of these protocols, De Groot discovered that grandmasters and masters thought much more efficiently and rapidly than players of lesser strength. Many thought processes are based on experience and technic, and the creative element appears mainly in the execution. On the basis of these results, he allowed the trial subjects to see a given position for 5 to 10 seconds. As soon as the observation period was over, the pieces were removed, and the trial subject was required to reproduce the position, whereby at the same time he was asked whether he had already seen a possible continuation move. The results were surprising in that strong players (Euwe among them) followed the position perfectly and also played the winning move. Less talented players made more errors and did not find the good continuation move.

The conclusion of this investigation is that perception is of great importance in chess; R.W. Jongman was therefore encouraged to investigate the matter further (Jongman 1968).

He conducted a similar investigation using more subjects and with several modifications (De Groot and Jongman 1968). Jongman's conclusion was the same: The talented player already made his selection from the first glance on the basis of his experience.

C. Learning effects of the study of chess

In the investigation by De Groot and Prins bearing the above title, an attempt was made to obtain an answer to the question of the effects of playing chess intensively for a long time on persons considered as "general teaching effects" (De Groot and Prins 1974). More specifically, the following topics were dealt with: learning to think, learning from errors, learning from practice, adaptation to rules, significance of concentration and insight, coping with fiasco and success, etc. According to De Groot, not only the acquisition of cognitive skills in a narrower sense is involved thereby, but also possible "fundamental insights" (experiences) relating to cognitive and emotional processes. (1)

(1) De Groot considers (learning) experiences fundamentally to be experiences recalled by the student and subjectively related for the actual development of important concepts he or she already had to some extent.

Although at first a number of noncognitive learning effects of chess instruction were reported (De Groot 1970), he later came around to the opinion that that term leads to a misunderstanding and that these learning effects are also to be considered cognitive to a certain extent on closer analysis (De Groot 1974a).

He regards the learning process of the developing chessplayer as a process in which the learning of rules and the learning of exceptions alternate with each other , resulting in a constantly more differentiating hierarchically structured system of operation arrangements - a program, a routine, or a subroutine. In terms of learning experiences, he describes it as the discovery, learning to see through, and learning to apply rules, and secondly the discovery, learning to have insight into, and learning to use exceptions to rules learned earlier.

The questions presented to the chessmasters in this investigation related to the learning of comprehending and solving problems, exercise and talent in learning, learning to concentrate and learning to devote one's energies, learning to observe rules, self-insight ability (1), learning to get along with tensions, learning to convert failure into success, learning to socialize aggression, and to deal with honor and fame (De Groot and Prins 1974b). A description of the results of the different questions would take us too far afield from our study, but we want to mention that five of the 14 chessmasters spoke of chess as a concentration exercise, and they also had to learn to think in advance and to learn how to analyze problems (De Groot and Prins 1974b, pp. 3, 15).

IV. SUMMARY AND CONCLUSION

The increase in the number of chessplayers occurring together with the "experimental" introduction of chess instruction in a number of primary and secondary schools in Belgium raises the question of the psychological importance of playing chess.

Although a great deal has been published on the origin, playing rules, players, openings, and middle and end games, very few scientific works have appeared on psychological processes in chess and possible advantages or disadvantages of chess for the development of the personality.

Allegations that factors such as concentration, analysis of problems, memory, and others participate in chess and are presumably further developed as a result are frequent (untested) statements made in the chess world (Merchiers 1975).

(1) Self-insight: A complex of mutally dependent possible learning experiences of fundamental nature, e.g.: I have learned: to accept my loss, to cope with success, to distinguish various performance fields, that some others are definitely better than I in some fields, etc.

PART 2: COGNITIVE DEVELOPMENT

I. BASIC PRINCIPLES OF JEAN PIAGET

A. Content, function, and structure

Piaget distinguishes the 3 main aspects presented above in cognition.

He considers "content" to be the raw uninterpreted conduct data. Example: The external behavior in a given test situation: "A child says: the balance dips because weight A is heavier than weight B." This content evolves during development, and it thus varies in successive periods.

The "function" includes general properties of cognitive activities applicable for each age and which represent the essence of the cognitive action. The "function" thus includes the way in which the cognitive structures (1) are formed. This involves 2 process of complementary action, "assimilation" (uptake of reality into already built structures) and "accomodation" (adaptation of the structures to new requirements of reality). If an equilibrium exists between assimilation and accomodation, Piaget speaks of adaptation. The effect of these functional aspects of intelligence remains constant during the entire cognitive development. In other words, assimilation, accomodation, and adaptation take place in both the sensory-motor period and at the formal operational level (see II).

Beside these functional aspects, Piaget also speaks of "organization." He thereby means that the structures at each level are characterized by a certain form of organization. In spite of the fact that intellectual structures evolve, at each level they exhibit totality characteristics in which all aspects are intimately related to each other and the whole.

According to Piaget, cognitive structures are the organized essences of intelligence itself. They cannot be observed directly, but they can be approached by an accurate analysis of externally perceptible behavior (contents). This takes place by the clinical method (see B). The "content" of intelligence stand completely on underlying structures. The structures are built up in the course of cognitive development by an active and complementary action of the functions. Structures such as pertinent contents evolve through different stages to a constantly greater complexity and equilibrium. The development of these structural aspects of intelligence represents the main object of Piaget's investigations.

Both the structural and content aspects of intelligence evolve, whereas the functional aspects (assimilation + accomodation = adaptation) and organization remain unchanged during the course of development, and therefore Piaget calls them the functional invariants (Verhofstadt 1975, pp. 17-19).

B. Clinical research method

Piaget is of the opinion that the test leader must follow

(1) See later text.

the thoughts of the child as closely as possible. The questions of the investigator must be adapted to the replies and the behavior (= content aspect of intelligence) of the trial subjects. By analysis of the replies and activities thus determined, he gains insight into the underlying cognitive structures. Piaget's investigative method thus excludes previously standardized interviews and tests.

The clinical method presents the great advantage of being able to follow the thought of the child in this way, but it is also true that the danger arises in case of less experienced investigators of being too suggestive or insufficiently so.

II. PHASE CLASSIFICATION ACCORDING TO JEAN PIAGET

A. General features of qualitative development stages

In Piaget's system, the panorama of the evolving structures is divided into phases in which qualitative similarities and differences serve as recognition marks in understanding the developmental process.

1. The concept of "phases"

In order to be able to speak of phases, the changes must be capable of taking place in leaps, which is the case with the intelligence structure. A certain abstraction of these phases becomes arbitrary if the behavior patterns of one phase cannot be distinguished qualitatively from behavioral patterns in a following phase.

2. Constant sequence of phases

The phase of concrete operations thus precedes the phase of formal operations in all children, for example. Nevertheless, the same level is not required for all branches for a given individual (see 6), and it is not necessary for all individuals to reach the final phase. The phases form an ordinal rather than an interval scale, i.e., a strict allotment of each phase to a certain time in life should not be made, as the influence of the medium can lead to advances or delays. Piaget speaks of "average " ages.

3. Hierarchic relations between successive phases

The structures of the earlier stages are integrated or combined with those of the following stages. The phase of formal operations will thus be impossible without the support of the phase of concrete operations.

4. The integrated character of phases

The structures of each stage achieve an integrated unit at the moment of its finish. Piaget speaks in this connection of "overall structures", whereby the different operations peculiar to a given period have attained the highest possible equilibrium and thus can occur structured and combined.

5. Preparation and equilibrium level of each phase

Each stage includes a preparation level which precedes the finish or equilibrium level. Example: The preparation level is located at around 11-12 years old for the formal operational stage, whereas the equilibrium level is situated at around 14-15 years of age. Structures are being organized in the preparation level, and they are still unstable and indistinct, but the way is already indicated toward a later level at which the structures form an organized and stable entity. It is only at that equilibrium level that the structures define the existing phase as the "overall structures" as described above.

In this sense, Piaget's opinion on the development of intelligence can be regarded as a progression of structural imbalance toward structural equilibrium which is itself always repeated at a higher functioning level.

6. Horizontal and vertical shifts

Piaget speaks of a shift because a subject is able to perform one task but not another, although according to him they are based on the same structures. The shift lies precisely in the fact that there is also an altering structural factor.

Horizontal shifting takes place within one period. Example: Conservation tests (among others, test with plasticine): at 7-8 years of age, the child states that the quantity remains unchanged but the weight alters. Constancy of weight comes only at around age 9 to 10.

Vertical shiftirg shows a repetition in various periods. For example, at a certain age a child can recognize an object from various angles. Some time later, the child can also visualize how a certain object looks from location B while the child is standing at location A at that moment. This shows a repetition which occurs at a distinctly different level of functioning. In other words, a hidden uniformity nevertheless exists in the difference occurring between the various levels.

7. Important features of the different stages

A first phase, namely the period of sensorimotor intelligence, located between ages 0 and 2 years old, is characterized by an action on purely external behaviorial level. There is thus no talk of true thought. Important characteristics and achievements develop in this phase, however (for example: intentionality, object permanence, language, etc.) which form a basis for the ability to act on a symbolic level in the succeeding phase. However, we will not discuss this period because it is of minor importance within the framework of our investigation.

This corresponds to the classification made by Inhelder and Piaget in the basic publication, "The Growth of Logical Thinking: From Childhood to Adolescence" by Jean Piaget and Barbel Imholdor.

We are considering as the first level not the sensorimotor period (which we do not include in our considerations) but instead preoperational thought.

1. Level 1: Preoperational thought

This stage, situated by Piaget between ages 2 and 6 years old, is regarded as a preparation level for concrete operational thought. He then also describes this subperiod in the form of imperfections in comparison with concrete operational thought. By means of speech, the child is indeed in a position to achieve a broader approach to activities, a better organization, and planning and "knowledge" of the surrounding world, but the whole leads to errors in thought because of insufficient interaction and mobile combination of these actions and the conceptual level. Due to incomplete coordination and a still incomplete organization of these actions at the conceptual level, the child is still too greatly influenced by striking and misleading suggestions of concrete perception. Example: The classical test of the pouring out of water for the conservation of mass: Two identical glasses (A and B), containing water, for example. The contents of B are poured into long narrow glass C. Reaction of the preoperational child: "There is more water in C than in A, because the water rises higher." Piaget explains this by declaring that the child is not yet capable of reversible thinking. He cannot free himself from his current concrete perception due to a deficiency in coordination of actions in the total system. He therefore cannot mentally return to the original action: "The water can be poured back into B, and then nothing is altered." The last reasoning leads to a logical necessity which is typical for concrete operational thought. In preoperational thought, only isolated actions occur which are not integrated into balanced organized systems such as in concrete operational thought (Verhofstadt, 1975, p. 44).

2. Level 2: Concrete operational thought

This concrete operational thought, characteristic for the age range of 6 to about 11 years old, is characterized by organized actions on a symbolic level. In contrast to the actions in the preoperational phase, these actions are now well integrated (not isolated) into organized and balanced systems with structural features. In other words, the structures of concrete operational thought are characterized by the ability to apply classic and relationship logic, whereby it becomes possible to systematically arrange and organize the experiences of objective reality in a systematic way. Piaget logically and mathematically calls all possible operations which can be processed into classes and relations the "groupings." A grouping (1) is an abstract structure related to the group (2) and the lattice (3).

(1) A grouping consists of a set of elements and an operation conducted on these elements, such that grouping features are maintained, except

for associativity, which is not always applicable because of special identity (tautology and absorption = lattice characteristics).

(2) A group is an abstract structure composed of a set of elements and an operation conducted on these elements such that the features of composition, associativity, identity, and reversibility are maintained.

(3) A lattice or grill is a partially arranged collection (reflective, asymetrical, transient), whereby a highest maximum limit and a minimum lower limit exists for each pair of elements.

A formal analysis of these logical mathematical structures lies outside the framework of our investigative goal (see Flavell, 1963, p. 213). One of the important features of these groupings is reversibility. The concrete operational child is indeed capable of reversible thought, which implies a mobile combination of actions on a conceptual level within balanced hierarchic systems of classes and relations.

However, restrictions on concrete operational thought exist:
1. Thought remains strongly bound to objects.
2. Thought remains limited to working with classes and relations (and not yet with judgments).
3. What is real is primarily what is possible.
4. The 2 forms of reversibility (see 3) occur close together without mutual integration.

The child is only capable of arranging data experienced in one way or another. He cannot yet pass beyond experience and is thus not yet competent in the field of the "possible" and the hypothetical, a limitation raised in the following period.

3. Level 3: Formal operational thought

Whereas the equilibrium level of concrete operations is reached at about age 11, formal thought develops in the course of the 12th year of life, capable of acting independently of random concrete situations and the particular framework peculiar to a test situation. Cognitive action can now also act on a hypothetical level. The equilibrium level of the formal operational stage is reached at about age 14-15, according to Piaget.

Important characteristics and the course of formal thinking are assessed by Piaget as follows. A constantly greater ability to "know" the surrounding world arises by expansion of the adaptation field; in addition to a concrete perceptible reality, it is now possible to think about this reality in hypothetical terms as well. In a given test situation (for example, a search for factors determining the elasticity of rods), the concrete operational child immediately goes into action and discovers a number of variables which exert an influence by classification (class logic) and relation logic (1).

(1) Many examples can be given, for example the formulation of definite laws in natural science problems (e.g., the swinging frequency of a pendulum), worked out by Piaget and Inhelder (1970). The different processes in children at concrete operational and formal operational are clearly demonstrated thereby.

However, the formal operational child does not proceed by experimenting but by studying material, not discovering the variables (for example, the length, thickness, and nature of the material) but by arriving at preliminary assumptions (thus also by concrete operations, such as classification and relation logic, which need not actually be carried out, however).

Further work takes place on these results (of concrete operations
- The isolated variables are not considered conclusions but hypotheses (which must be tested), for example the hypothesis: "The length can exert an influence on the elasticity of a bar."
- The formal operational child sees all possible relations among these variables at the start.

We thus saw that "the possible precedes the concrete." Concrete reality is not underestimated, but it is only one of the many possibilities which can take place.

We also say that in formal operational thought a hypothetical thought is considered with hypotheses which must be tested (this in contrast to concrete operational thought, which acts with conclusions based on concrete actual happenings).

In addition, the child foresees not only variables but all possible combinations among the variables. The elements of the combination are assessed. He thus achieves an expansion of class and relation logic to judgment logic with the possibility of interpropositional thought (relations among judgments).

The child also thinks of the correctness or incorrectness of combinations of hypotheses or judgments. It is thus possible to call this judgment-logical thought to the second power.

In order not to forget any possible combination, the formal operational child subjects the isolated variables (concerning which it is judged operations are possible) to a combination analysis, i.e., a general classification of judgments by combining them one by one, two by two, etc. We will develop the most important feature of formal operational thought in the third part on the basis of the liquid test.

The drawing up of a combination is not any goal in itself, however. It is only a means to this goal, e.g., determining the causal structure in a certain test situation. All possible combinations should be tested in the experiment when the child is asked to indicate which actually occur. This experimentation takes place according to a well-developed design, e.g., by dissociation of factors whereby only the test factor is varied whereas the others are kept constant. (Analogously to the principle of isolating variation - see Baekelmans 1973.) According to Piaget, the adaptation of this scientific method is a clear indication that, before a combination is set up, the adolescent is completely aware of this complex process.

A final characteristic closely connected with the foregoing consists in the fact that no synthesis occurs between the 2 forms of reversibility (Verhofstadt 1975). This aspect of integration of inversion and reciprocity, which appears most clearly in the ability to apply the INRC group, is also developed and illustrated in the third part by means of the balance test.

As was stated, the sequence of stages is constant, but the tempo varies greatly from one social environment to the next. According to Piaget, mainly the opening of formal operations should be very closely related to efficient medium stimulation, which was the case for the test subjects Piaget had (children from the best schools in Geneva).

> "The experiments on which the above-mentioned results are based were carried out with secondary school children, 11-15 years, taken from the better schools in Geneva ... Other information gathered about adults in Nancy, France, and adolescents of different levels in New York has also shown that we cannot generalize in all subjects the conclusion of our research which was, perhaps, based on a somewhat privileged population." (Piaget 1972, p. 6)

This discussion indicates that the age limits given for formal operational thought (namely 11-12 years up to 14-15 years) are of low validity in ideal environmental conditions. The following citation from Piaget also points in the same direction:

> "In the case of poor stimulation and activity, it goes without saying that the development of the first 3 of the 4 periods mentioned above will be slowed down. When it comes to formal thought, we could propose that there will be an even greater retardation in its formation (for example, between 15 and 20 years and not 11 and 15 years); or that perhaps in extremely disadvantageous conditions, such a type of thought will never really take shape or will only develop in those individuals who change their environment while development is still possible." (Piaget 1972, p. 7)

I. SUMMARY AND CONCLUSION

Within the framework of this investigation, we consider Piaget to be especially important, as he is one of the few authors to attempt to show that at around the end of the elementary school period the child develops new formal thought structures which exhibit distinct qualitative differences in comparison with concrete operational structures.

Piaget considers the most important characteristic of formal thought to be the ability to adapt combinative features and the INRC group. On the basis of numerous test situations, he attempted to demonstrate the existence of both thought structures in preadolescents (compare Piaget and Inhelder 1970).

The development from the concrete to the formal operational thought level, which is believed to take place in a similar way in

all children, reaching its finish or an equilibrium at around 14-15 years of age, which is indeed the case for the entire cognitive development, in part a hereditary situation.

Both the initial age and the age at which the equilibrium level of formal operations is reached are subject to environmental influences, however, and they can thus vary from one individual to the next. Where the average age is 14-15 years old, an optimally stimulating environment can advance control of formal thought structures, according to Piaget, and on the other hand in a "stimulus-poor" environment cognitive development runs more slowly or a higher developmental stage may not be reached. We would like to point out that the age limits given by Piaget for formal operational thought mainly apply for a "stimulus-rich" environment.

PART 3: EXPERIMENTAL INVESTIGATION

I. PROBLEM PRESENTATION

In the first part, we mentioned that concentration, analysis of problems, memory, and other factors participate in chessplaying and presumably are also further developed. In the second part, we discussed Piaget's theory, to the effect that, in the development of concrete operational to formal operational thought, certain stimuli from the environment are essential in addition to inherent innate factors. In addition, Piaget's theory leads to the use of test situations (mainly adaptation of combinative and the INRC group) which can decide at what cognitive level a child is.

We raise the question of whether chess instruction may not be able to exert a favorably stimulating effect on the formation of the formal operational thought level. The ability to foresee a number of possible chess moves along with all possible countermoves by the opponent evidently requires the establishment of a combination and then a dissociation of factors in order to select the "best" move from the whole. As the use of a combinative group and the INRC group (1) occurs in chessplaying and thereby can also be applied, it can be considered that learning to apply these 2 logical mathematical structures in chessplaying is perhaps also transferable to other problems outside of chess.

In this third part, we will consider developing an investigative framework on the problem of whether formal operational thought can be advanced by giving instruction in chess. We will not thereby limit ourselves to following the influence of chess on the formation of the formal operational thought level, but we will also attempt to study the influence of chess on school achievements and intelligence tests.

(1) Both formal operational structures are illustrated further.

II. OVERALL INVESTIGATION DESIGN

A. The "posttest-only control group" design

In this design, the investigator forms 2 random groups (1). He does not give any pretest, gives a certain manipulation to one of the groups, and he later gives a posttest to both groups.

This investigative design, although very useful, is often underestimated in psychological studies because it was believed for a long time that a pretest was absolutely necessary. Nevertheless, the design presents almost the same possibilities as many other investigative patterns (2) such as the "solomon four-group"design (3) or the "pretest-posttest control group" pattern (4). Testing (5) and interaction between testing and treatment (6) are under control. The "posttest-only control group" plan is especially indicated in situations in which it is difficult to conduct a pretest or it is even entirely undesirable. This design controls all factors

which are disturbing to the internal validity (7) and moreover a factor which is important for the external validity (8). It is an investigative design which is much more economical than the above mentioned other experimental study plans. (Clincke, Demeyer, Heyerick, and Vandierendonck 1973, p. 106).

(1) Two random groups are formed in a completely randomized way (or by drawing lots) to divide the entire sample taken at random into 2 groups. Each element then has as much chance to get into one group as into the other.

(2) An experimental research design is distinguished from pre-experimental or quasiexperimental plans, for example, by the introduction of a true control group. It is called experimental because manipulation by the investigator takes place.

(3) In the "solomon four-group" design, the investigator prepares 4 random groups. Two groups are considered to be in the "pretest-posttest control group" and are thus given a pretest. The other 2 groups are not subjected to a pretest. The same posttest was given to all groups.

(4) In the "pretest-posttest control group" design, the investigator sets up 2 random groups. Both groups take the same pretest, a treatment is given to one group, and after that both groups take the same posttest.

(5) Testing is the effect of the first test given (pretest) on the scores of the second test given (posttest).

(6) Interaction between testing and treatment should be understood in the sense of an interaction between pretest and manipulation. The fact that a pretest is given can cause a warming-up effect on the subjects.

(7) Internal validity: This relates to the problem of whether the effects encountered are actually to be ascribed to the experimental manipulation of the independent variables in the specific experimental situations. An investigative design is internally valid when the effects obtained cannot be explained by external factors.

(8) External validity: This relates to the problem of the generalizing ability of the effects found.

We selected the "posttest-only control group" plan for 2 main reasons: it makes use of the randomization principle, and no pretest is given.

1. The randomization principle

Advantages of this experimental principle in comparison with "matching" (9), for example, include among others:

a) Due to randomization, all variables are distributed at random over the resulting groups. As a result, the groups obtained (probably) are uniform for all variables, both the variables which exert an influence and those which have no influence. This is of great importance for our investigation, as we do not clearly know which variables exert an influence on the formation of the formal operational thought level.

b) The usual statistical technics can be used when randomization is applied, whereas in matching technics must be used intended for correlated groups.

c) Results obtained on groups formed by randomization provide a great generalizability.

d) If certain trial subjects drop out during the investigation, their loss can be corrected.

Without application of the randomization principle, there was a possibility of setting up a "nonequivalent control group" design, since we had 2 classes which could be considered equivalent (see B.1). The quasiexperimental investigative concept should be considered maintained, as we gave chess instruction to all students in one class, whereas in the other class chess instruction was not to be given to any student. In spite of the fact that it might be supposed that both classes were alike in all variables at the outset, since they were "approximately" random in composition, we did not select this investigative design since the influence of the teachers can also be of importance. It is thus not impossible for the first class to have better posttests, not because of the chess instruction but because of a more stimulating teacher. Randomization over the total group (both classes taken together) was the solution in this sense of the problem of excluding or minimizing the influence of the teachers (see below).

2. No pretest

The decision not to give any pretest was made, among other reasons, in order to exclude as many reactive arrangements (10) as possible. We considered that, if a pretest was given, the trial subject would clearly see the experimental character of the instruction and would thus perhaps also behave according to the expectations of the experiment. The introduction of the randomization principle already introduced a reactive arrangement in this sense.

B. Concrete execution of our study plan

1. Trial groups

a) Ages of the pupils

We selected our trial group so that, at any time the posttest

(9) Matching is the directed and intentional synchronizing in certain variables.

(10) Reactive arrangement: This term indicates what is artificial in each experimental situation. The fact that a human subject knows that he has been included in an experiment, for example by randomization, pretesting, strange teachers, observers, etc. makes the situation artificial and cause a deviation from natural conditions.

was made, the students, according to the development theory of Piaget, would have reached an equilibrium level of concrete operations in an ideally stimulating environment and would be able to carry out their first hesitant operations (see preparation level characterized by imbalance) at the formal operational level (according to Piaget: ±11-12 years old).

In addition, we wanted to give the experimental group chess lessons as long as possible, preferably for 2 scholastic years, in order to bring them to as high a chess level as possible.

It was impossible to begin from that standpoint with children from the 6th grade as presumably a number of them would no longer remain in the same school in the following school year, which would affect both further chess instruction and also the taking of the post-tests.

Students who were in the first year of secondary school also did not come into consideration, as there was a constantly greater chance that after 2 years practically all of them would have reached the level of formal operational thought set up by Piaget. A possible differentiation between chessplayers and non-chessplayers after 2 years might then be less or not be able to develop at all.

It was therefore decided to begin with students from the fifth scholastic year in elementary school who would be able to receive chess instruction during that school year (1974-75) and the following (sixth grade) school year (1975-76). At the beginning of the chess lessons, these students had an average age of 10 years seven months old and in the post-tests 11 years 11 months old. Preadolescents were therefore involved whereby, according to Piaget's theory, very little chance existed that they would have reached an equilibrium level of formal operations.

b) Choice of the school

First of all, choice was given to a school in which it would be possible to give chess instruction as one of the sociocultural activities on Wednesday afternoons. However, this appeared impossible as usually not all of the children were taking weekly sociocultural activities. A selection in this way could not be permitted because of the methodological implication of the limited generalizability of the results.

The need for a total trial group of chessplayers and non-chessplayers of at least 30 students supported the already mentioned implication of having a group of 2 classes.

With respect to sex, preference was given to boys, as less experience was available in giving chess instruction to girls.

The selection, following consultations with a number of schools, of beginning chess instruction in the municipal elementary boy's school at Assenede was particularly determined by the following reasons:

1. There were two fifth grades of 20 students each. The total trial group thus consisted of 40 students, which satisfied our minimum standard of 30 trial subjects.

2. The school management gave permission to give chess instruction in one of the lesson rooms to a randomly selected group of 20 students weekly during the school years of 1974-75 and 1975-76 on Friday afternoon following the normal lesson hours, from 3:30 p.m. to 4:30 p.m.

3. A series of tests were given annually to the students of the sixth grade by the Department of Studies and Occupational Orientation of Eeklo, which could prove useful together with the other post-tests.

We once again want to point out (also see part 1) that it was impossible to take 2 existing groups, especially one group which had received or could receive chess instruction at a given school from a teacher or from someone from a local chess club for some time, and another "equivalent" group of students unaquainted with chess. The fact that the chess instruction to be introduced at certain schools (sporadically in Belgium in 1974) was not at all compulsory at the outset already resulted in a preliminary selection of the chess group at the outset. In addition, for such an instruction system the number of students who ended the course was small in comparison with the number who started, since many students (and especially those with the lowest achievements) did not end the lesson series. In order to avoid dropouts by students during our chess lessons, both the teacher and the school management gave the impression that the chess course was compulsory, so that even those less interested would nevertheless keep taking lessons (also see Frank 1973).

c) Division of pupils into chessplayers and nonchessplayers

As already mentioned, the total group was divided into two groups at random. Out of the total group of 40 name cards, 20 were selected to take chess instruction. The remaining 20 pupils were not to be considered for instruction and were to serve as a control group. It was a random result that the group of 20 chessplayers accidentally consisted of 10 pupils from 5A and 10 pupils from 5B. We already stated that the possible unlike influence of the teachers was neutralized by this trial-group composition.

2. Chess instruction and alternative activity

a) Chess instruction

1. Method

In part 1 (II, B, 1), we saw that Jeugdschaak (Chess for Youths) by B. Withuis was the method most used in Holland for pupils at the end of elementary school and the beginning of secondary school.

With the exception of the part relating to Dutch chess life (pp. 55-60 of the original), this method was largely taken over in connection with the first 2 parts.
The theoretical presentation, diagrams, and openings were prepared in stencils and were given to the pupils as chapters after the end of each lesson. As supplementary work in the first theory lessons, a fill-in form was also given as homework in all cases. These exercises were turned in at the next class and assessed in a usual way.

Instructor

Within the framework of the investigation goal, it was generally recommended that I myself was not to give the chess lessons,as the resulting reciprocal relation between the pupils and instructors might influence the taking of the follow-up tests and the results (affecting the trial group more than the control group; see II, B, 3).

However, the teacher must satisfy the following requirements:

1. Have knowledge of the field of chess and have the necessary material available.

2. Some knowledge of teaching.

3. Be able to prepare weekly instruction and to give the chess lesson on Friday afternoon .

Because of the impossibility of finding someone to satisfy these prerequisites, I myself had to serve as teacher. However, this meant that someone else would have to give the follow-up tests. This did not constitute a problem for the school results (teacher) or for the school advancement and intelligence tests (Department of Studies and Occupational Orientation), but it was so for the Piaget tests, where, however, we were finally able to find someone to give the tests.

Chess material

One chessboard and one chess set was made available at the outset for every 2 pupils. They later also received each a note sheet, and they were later also given the opportunity to play some games with chess clocks.
The presentation of the rules of chess and problems was clearly shown in the class by means of a demonstration board (1 m x 1 m).

Care was taken for the pupils to sit together with someone else at one board and for each child to solve chess problems regularly in front of the class at the demonstration board.

2. Course of the chess instruction

The framework of the investigation, the choice of the school,

the setting up of the groups, and the stencilling of the lessons were settled for the first trimester of 1974-75, so that it was possible to begin the lessons in January 1975 following the Christmas vacation.

A total of 42 chess lessons were given from January 1975 to May 1976.
Whereas at the beginning the lessons mainly dealt with the various chess rules, the emphasis was shifted toward the end to the playing of games, especially within the group of 20.

In general, it was found that the first theoretical lessons dragged on quite a bit longer than anticipated in comparison with the "apparent" greater progress of older subjects with this chess method.
This can be explained as follows: Elsewhere work always took place with interested pupils who were able to offer more time to chess not only during the weekly chess classes but also outside them, with their friends, so that they apparently acquired the first part more rapidly. However, it was frequently the case that a number of children, presumably perhaps the majority, were acquainted with the rules of chess, whereas a few children remained behind. This may also explain the high number of children who spontaneously dropped out after a number of chess lessons. It was desired to avoid this difficulty as much as possible, and for this reason certain chapters were repeated not once but several times and developed more deeply with further exercises, so that each pupil had acquired the beginning stages of chess before beginning with games. It was then hoped that all children would continue the studies. On average, only one pupil was absent per lesson, with a good reason (differing, not always the same excuse).

After explaining the possible moves of each chess piece, a number of lessons were introduced with exercises on mate. After these exercises had been solved by everyone, a complete game was played. Recording the moves was compulsory.
After most of the chess rules were presented, the time for exercises and games gradually became greater in comparison with the theoretical presentation. Until the last lesson, however, there were always a number of remarks on theoretical considerations given before beginning the games.
Five sessions were also devoted to simultaneous games, and there was also participation in the East Flemish interscholastic championship, and, in the chess tournament for elementary schools on the occasion of the Belgian youth championship, a good third place was obtained. It should be mentioned in this connection that the opponents in such tournaments were indeed of the same age, but they were mostly children whose parents had already taught them chess for some time and were intensely devoted to chess.

In spite of the fact that the post-tests were given in the month of April, chess instruction was continued further until the end of May 1976 in order not to create the impression that some connection existed between the taking of the tests and the chess instruction

3. Evaluation of chess

In order to be able to investigate the possible connection between chess and other factors, the need arose for obtaining a score on the level of chess of each pupil in the chess group.

A school championship covering 7 games was organized for that purpose from January 1976 to May 1976. On average, 2 sessions were necessary for all the games from one round. This praiseworthy slow playing tempo was characteristic for the group in comparison with many other children who at that age played games too rapidly and gave too little thought to all possible moves and countermoves. If certain pupils nevertheless played their games rapidly, they engaged in simultaneous play against the teacher in the remaining time.
The school championship was played according to the Swiss system (1), and the scores were 3 points for a win, 2 for a draw, and 1 for a loss.
Contrary to the results from the fill-in exercises and examinations, the results of the school championship were displayed in the classroom. This was not done earlier in order not to discourage losing pupils (the emphasis was always laid on the fact that it was most important to play a beautiful game, even if it was lost) and in addition in order not to arouse any interest in chess in the control group.

b) Alternative activity

The presenting of chess instruction on Friday afternoon after the normal lesson hours was also favorable, since the control group went home before the beginning of the chess lessons and thus did not receive any systematic instruction instead of chess. A possible parallel influencing comparable to that of chess instruction by a certain other activity was thus practically excluded.

3. Post-tests

a) Piaget tests

Preliminary remarks

The Piaget tests were the most important post-tests. In addition, we took the scholastic results and PMS tests into consideration as well, as we were able to obtain them respectively from the teachers and from the Department of Studies and Occupational Orientation (see 3b,c).

1. Choice of tests

Within the framework of this investigation, the Piaget tests were intended to satisfy a number of requirements.

With respect to the degree of difficulty, the tests could only

(1) Swiss system: A generally recognized tournament system which offers the best guarantees that a reliable classification of the players is obtained after 7 rounds, for example.

be partially solved by children who were at the concrete operational thought level, whereas children who had attained an equilibrium level of formal operational thought were able to solve the tasks completely and in a correct way. In other words, the tests made it possible to determine at what level, with substages, the trial subject was, going from concrete operational thought toward the unbalanced stage of formal operational thought toward the finish level of the latter period.

The requirement of the determination and a correct demarcation of the different stages in the solution method was also involved in this goal.

The tests also had to relate to easy material. The test with the hydraulic press was difficult to execute in this sense (1).

The time factor also plays an important part. As the trial group consisted of 40 children, the total test time per pupil preferably amounted to less than 1 hour. (2) (+ pl. problem see 2-a)

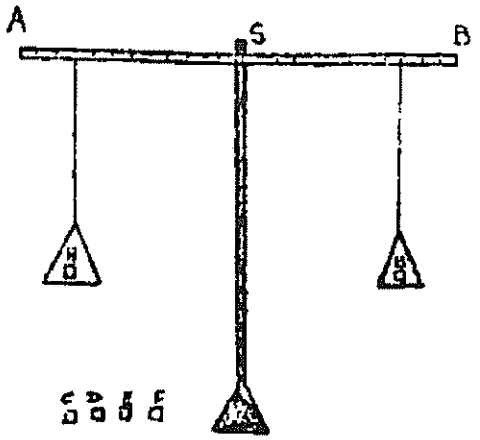
It was already stated that Piaget considered the handling of the combination (with lattice structure) and the INRC group as very important features of formal operational structures. Both features thus were able to be investigated by our tests.

In consideration of the foregoing requirements, two tests were chosen, the balance test (for testing the INRC group) and the liquid test (for testing the combination), whereby the total uptake time per person was between 30 and 45 minutes (see earlier remarks).

a. Balance test (3)

In this balance test, a balance was used whereby a horizontal slat (AB) can rotate at the top around the fulcrum (S). The lath forms a left arm (AS) and a right arm (SB); both are of equal length, and each has the same number of suspension points at which a scale can be suspended. Two scales, one at the left and one at the right arm, hang at the same height (H) when no weight or the same weight is lying in each of the$_M$ and when they hang at the same distance from S. Fourteen suspension points arranged at the same distance are provided on the left and right arms. A number of weights, called A, B, C, D ... also are included with the balance.

(1) L'equilibre de la presse hydraulique - see Inhelder and Piaget 1970, pp. 131-143.
(2) Individual test times only are involved here, so that the total test time for the group amounted to about 40 hours.
(3) See Inhelder and Piaget, 1970, pp. 144-158.



This test with the balance satisfies our above mentioned requirements. Piaget clearly describes a number of stages and intermediate stages on the way to a good and complete solution of this test.
He experimentally determined that the balance test is correctly and completely solved only by children who had attained the equilibrium level of formal operational thought.
The requirements with respect to the material to be used (the balance was itself to be made of wood) and the time allowance (around 15 minutes) are satisfied in this test.

We had already stated that formal thought is able to distinguish inversion or negation (reversibility form of classes, represented by N) and reciprocity or reciprocal (reversibility form of relations, represented by R).

"A child will exclusively handle concrete operations of classes, relations, or numbers whose structure does not exceed the level of elementary logical 'groupings' or additive and multiplicative numerical groups; he thus ends in using the two supplementary forms of reversibility (inversion for classes and numbers and reciprocity for relations) but without fusing them in the single and total system which characterizes formal logic." (Inhelder and Piaget, 1970, p. 298)

The difference between inversion (N) and reciprocity (R) consists in the fact that the original operation is literally annulled by the inversion, whereas by reciprocity the original operation is not annulled (the terms are not modified, only the way in which the relation is expressed runs differently). The essential feature of reciprocity is a modification of the relation with preservation of the terms.

In test situations, an inversion operation signifies, for example, removing a weight which had previously been placed; the original operation was thus completely annulled.

In a reciprocal operation, on the other hand, the original operation is to be retained but its effect is to be neutralized; in the balance test, for example, the weight is not removed (=N) but the arm along the same side is shortened by moving the plate closer to the fulcrum (=R).

According to Piaget, formal thought can work with a 4-group, namely the group with the 4 transformations or the INRC group.
(1) This 4-group is achieved in connection with a number of physical problems (2) in the physical INRC group and in connection with logical problems in the logical INRC group.(3)

We here adapt the physical INRC group to the action of the balance.

example: original state of the balance:
- both scales without weight
- both scales evenly distant from the fulcrum

Transformations

- only with the left scale and arm

(1) weight in the left scale ---> balance disrupted = identity
(2) weight removed ---> balance restored = negation
(3) The equilibrium can also be restored by shortening the arm = (I remains) = reciprocal
(4) The balance can also be disrupted in the original state by lengthening the arm = correlation
(= inversion of R and correlation of I)

- with both scales

example: The balance is disrupted by a weight in the left scale.
Reciprocal operations: - add a weight to the right scale
- lengthen the right arm by placing the scale farther away from S.

Summary; each operation within a physical system which possesses INRC-group properties can be represented by 2 types of opposite operations:
- its negation, which directly annuls the operation
- its reciprocal, which leaves the operation itself unimpaired but neutralizes its effect.

According to Piaget, being able to handle this INRC group provides

(1) I = identity, N = negation, R = reciprocal, C = correlation.
(2) Not all physical systems are involved here (see Verhofstadt 1973, p. 72).
(3) This logical INRC group relates to direct operations (transformations) on judgments. We limit ourselves in this investigation, however, to the physical INRC group, which according to Piaget is based on the same underlying structure.

a model, a reference framework for formal thought. It appeared from tests that children at the concrete operational level did not go much beyond the identification and manipulation of one opposite force (usually inversion); on the other hand, the formal operational level was characterized by identification of the 4 operations, and moreover it was possible to consider them in a system in which each operation had a specific relation to the others. (Verhofstadt 1973, p. 74)

b. Liquid test (1)

In this test, the test director offers the child 4 bottles, each containing a colorless and odorless liquid (A,B,C,D)(2). A fifth liquid g (3), also colorless and odorless, is contained in a drop counter and should form a yellowish red color with one or more of the 4 other liquids (with A and C, for example). According to one example, the test subject is requested to obtain the corresponding yellowish red color by making use of the 4 liquids in the bottles and the liquid in the drop counter. The test subject also has a number of glasses at his disposal for possible experimentation. Pencil and paper are also lying on the table, so that the combinations tested can be recorded.

Piaget and Inhelder also reported various stages in a good solution of the problem in this test after a number of trials. Children who reached the equilibrium state of formal operational thought solved the test completely satisfactorily, among other means by forming a combination.
This is a system in which all possible combinations are represented and are tested by means of dissociation of factors in order to derive the active factors.

"The formation of the logic of proposals, which itself marks the appearance of formal thought, is conditioned, as we have constantly observed, by the establishment of a combination. Necessary to the construction of a 'whole of the parts', this combination is mainfested by the possibility of connecting the base correspondences or combinations among themselves in all ways in order to draw the implication, separation, exclusion, etc. relations from them which they set up by these connections." (Inhelder and Piaget 1970, p. 97)

The establishment of a combination can be expressed as follows. With 2 judgments (hypotheses), for example p and q, it is possible to provisionally form 4 basic combinations: $(p.q)(p.\overline{q})$ $(\overline{p}.q)$ $(\overline{p}.\overline{q})$. They are identical, which should give a simple multiplication of classes: $(P+\overline{P}) \times (Q+\overline{Q}) = PQ + P\overline{Q} + \overline{P}Q + \overline{P}\overline{Q}$. According to Piaget, this operation is already possible at around age 7-8. The new thought, actually logical judgment thought, consists in the fact that these

(1) See Inhelder and Piaget 1970, pp. 97-109.
(2) Liquid A is dilute sulfuric acid; B is water; C is hydrogen peroxide, and D is thiosulfate (a substance which decolors A+C+g).
(3) Liquid g is potassium iodide. See page 40 for layout of liquid test.

four basic combinations, which we will call 1, 2, 3 and 4, can be combined systematically to form 16 possible combinations: 1, 2, 3, 4, 12, 13, 14, 23, 24, 34, 123, 124, 134, 234, 1234 and 0. On the basis of tests, Piaget was indeed able to show that alternately or repeatedly each of the 16 formal propositions (hypotheses to the second power) was accepted or rejected before a subject adopted a hypothesis. It is not claimed that a child is able to knowingly set up such a developed combination in the formal operational phase, and neither is the child able to explicitly call upon or record all these combinations. For that matter, Piaget also was unable to determine this network in its total scope in a single trial subject. He derived the existence of this combination from the tests performed by the child. "Although no implicit consideration was given to all possible solutions (a very large number of which were already excluded at the outset since they could be seen not to occur), it is also true that this possibility was not tested systematically." (Piaget)

> "This is why the use of the 'all things otherwise equal' test process, as simple as it may appear, in itself constitutes a certain index of the intervention of this combination; without a search for true combinations within the possible combinations, the subject would not test the need to pass beyond the given associations to dissociate the factors." (Inhelder and Piaget 1970, p. 244)

2. The giving of the tests

a. Test-director problem

In consideration of the already mentioned need to turn over the giving of Piaget's post-tests to a "neutral" test director other than the person who was giving the chess instruction, such a person had to be found.
One of the methods for recording the confirmation value (1) of our investigation lay in the exclusion of other interpretations. The "self-fulfilling prophecy"-effect is thereby a related and influential phenomenon. It was intended for the results of the investigation to be determined to a great extent by the personal observations of the investigator (Clincke, Demeyer, Heyerick, and Vandierendonck 1973, p. 73 (compare Rosenthal effect).
In other words, in the giving of Piaget's post-tests a possibility existed that the results would not be objective as I, because of the fact that I had been giving the chess instruction, had knowingly or unconsciously passed the judgment of "intelligent," "bright," or "unintelligent" on certain children. Certain performances in test situations could thus be interpreted incorrectly, so that the picture of the performance might be interpreted falsely with respect to the contribution of the trial subject. Another possibility was that certain children from the control group (non-chessplayers) would intentionally be assessed as achieving lower levels as the "chess teacher" would regard them negatively as they were not selected to take lessons. In other words, falsifications of the results

(1) Confirmation value: the extent to which the occurrence of a prediction contributes to the development of the hypothesis.

of the post-tests when given by the chess teacher could thus knowingly or unknowingly lead to falsifications of results both on the part of the test director and the test subject to the extent that their relationship is negative or positive. In order to avoid this situation, a "neutral" test director thus had to be found who would certainly not have any relationship to the chess instruction given the children. Because of this requirement, the test director would also have to have some teaching knowledge and to be acquainted with the clinical method. This matter was investigated in a number of prelim nary studies. (1) In order to be able to monitor the influence of the test director, the tests were recorded on tapes which were given in advance to each trial subject.

b. Time and place for taking the tests

As the 2 tests, the balance and liquid tests, were given to a presumed test group of 40 pupils (2), it was necessary for both the room and the test director to be available for one week every day from morning to evening. For this reason, the second week of the Easter vacation was selected, from Monday April 12 until and including Friday April 16, 1976.

The taking of the tests during this vacation period presented the additional advantage that the pupils had less contact with each other, which somewhat restricted the discussion of the nature and the solution of the tests.

On the other hand, it was impossible to give the tests for less than 5 days, as a time of 8 hours per day was already required of the test director with a method (dinical method) which required precise observation and insight into the thought processes of the trial subjects.

It was therefore also impossible to use several test directors not only because of the material but because the comparability of the results might become questionable as a result.

The difficulty of getting the children to school during the vacation period was obviated with the aid of the school administration, which sent out a notice to the parents:

"All pupils in the sixth grade are requested to come to school for half an hour during the Easter vacation to take a certain test.

(1) See below.
(2) It was later found, however, that 3 pupils from the control group had left the school in the course of the sixth-grade school year. They were 2 pupils from 6A and one from 6B. All three were non-chessplayers.
(3) Both tests required about 15 minutes. This included an introductory and a later talk of a total of about 5 minutes. The extra time was necessary for explaining the material for the liquid test.

The day and the time will be reported on the class agenda. Dear parents, we urgently request your cooperation. Take your boys to school for this short test. We give your our best thanks in advance."

This letter sent out in the name of the school administration resulted in the appearance of 33 out of the 37 children at the times indicated. The Piaget tests were given to the 4 other children, two of whom were on vacation abroad during the Easter vacation, in the course of the following week. No connection with the chess instruction was thus given in the above mentioned letter.

Since the children were unaware of the connection, it can also be assumed that an association of the test with the chess instruction was practically excluded. The teachers were also requested not to state, in case of questions, that the investigation related to "chess and cognitive development."

Seven pupils were thus scheduled per day from Monday April 12 to Friday April 16, 1976, at the times 8:30 a.m., 9:30 a.m., 10:30 a.m., 11:30 a.m., 2 p.m., 3 p.m. and 4 p.m. (1). Concerning the sequence of the taking of the tests, the pupils from 6A came first, followed by those in 6B, taken in alphabetical order.

c. Preliminary tests

The taking of the Piaget tests in subjects of the same age and sex, to be started with the actual testing of the experimental and control groups, had a double purpose:

1. To acquaint the test director with the tests and the "clinical investigation method" of Piaget.

2. To be able to discover and eliminate possible defects in the presentation of problems in due time.

Both in these preliminary tests and in the actual tests, the basic rule was always maintained: " The test director must always analyze the performances and formulations of the child as accurately as possible and continuously study the motivation of these performances, although without thereby himself presenting solutions."

The first preliminary test was given on March 17, 1976 to a pupil, I.V., 11 years six months old, coming from a district other than Assenede. (2) I myself gave the balance test, both in order to test the way it was presented for the benefit of the attendant test director and in order to have a good course in the first contact with trial subjects. After that, the actual test director undertook the liquid test. Following the tests, a discussion was held with Prof. L. Verhofstadt, who had observed the tests. This resulted in an adaptation of a correct choice of wording for the presentation of the test in the case of the liquid test. It is not necessary to

(1) Five days to 7 pupils per day amounted to 35 tests (out of the original trial group of 40 subjects, three had dropped out, and in addition two children who had participated were on vacation).
(2) This was also the case for the second and third preliminary tests, so that further discussion with the actual pupils was almost excluded.

discuss the matter further, except that the child was told he could use everything available on the table, and the objects were named: liquids in bottles, liquid in the drop counter, glasses, paper, and pencil. This was done in the case of the two items last mentioned in order to avoid the possibility that some pupil might not conceive of using the paper and pencil for recording combinations possibly made and thus remember them better.
Both before and after the test, a brief discussion was held with the trial subject in order to establish a better relationship with the subject, first of all, and later to find out what the pupil thought of the tests (difficult or easy, solvable in other ways, etc.). It was found that, in lack of an optimum friendly relationship between test director and trial subject, the thought processes of the latter could deteriorate in the execution of a certain action, for example.

The second preliminary test was held on March 24, 1976. Trial subject G.B., age 12 years 1 month, now handled the tests better than the first subject. The future test director conducted both tests. The relationship between test director and pupil was now much better, so that the child handled his thought processes better than the child in the first preliminary test.

As the third trial subject for a preliminary test, a Dutch child was selected, H.C., age 13, who in spite of his youth had achieved a high chess level both nationally (Dutch Youth champion for 1975) and internationally. This test was conducted with the aid of the Laboratory for Experimental, Differential and Genetic Psychology of the Gent Federal University on television (1).
A comprehensive discussion was thus possible later, and the subject was himself able to detect some minor faults. (2)

Following this third preliminary test, it was decided that the test director and the test method were ready for the actual tests in the trial and control groups.

d. Definitive taking of the balance test

We present the following example to illustrate the way the test was given. A trial subject who gave good results, no. 124, was involved. (3)

Trial subject: 124
Birth date: 6/16/64 - Age: 11 years 10 months.
Test on Friday April 16 from 9:30 to 10:20 a.m. Duration: 50 minutes.
Result: score for the balance test: 4
score for the liquid test: 4 (4)

Test director: Ah, ah, you are here. You are ...
Trial subject: Luc (5)
Test director: And how have you been during the vacation time?
Trial subject: Well.
Test director: Luc, sit down in this chair. And what have you been doing during the vacation time?
Trial subject: I have been swimming and helping my father.

(See next page for footnotes.)

Test director: Ha, ha, I also helped my father. In what way did you help yours?
Trial subject: I rode with him on the tractor on the land ...
Test director: Aren't you displeased that you had to come to school again one day during your vacation?
Triat subject: (Laughs once). No, it is not for long, according to the schoolmaster.
Test director: Ah, yes, I know all about the schoolmaster. Did he also tell you what you would have to do here?
Trial subject: No.
Test director: But perhaps you know something from your schoolmates?
Trial subject: My friend, G.C., had to come for only half an hour.
Test director: Ah, ah. But it is not the same time for everyone. Shall we begin ?
Trial subject: (Laughs)
Test director: First of all, I would like to ask you to listen carefully and also think carefully before you reply. I would also appreciate your telling me what you are thinking as loudly as possible and why you are doing a given thing. Agreed?
I will be taking down everything on a tape, but that makes no difference, right? I would otherwise have to write down everything, and that would be too inconvenient. Well, Luc, look over here. What is this? Do you know what it is?
Trial subject: A balance.
Test director: Just so, this is a balance. It is indeed a balance. And what do you see on the balance?
Trial subject: Two cords ... two weighers ...
Test director: Two weighers, let us call them 2 scales. Very good. And what else do you see?
Trial subject: A rod.
Test director: Yes, we call it the arm of our balance. It actually has 2 parts, a left arm, from here to here, and a right arm from here to here. What else do you see?
Trial subject: Weights A,B,C,D (6)

(1) The 2 preliminary tests were also made at that department, but without the use of television; only a tape recorder was used.
(2) It was a remarkable finding that this third trial subject gave much better results than the earlier ones. A precise presentation of these three preliminary tests is not given here, as they are of lesser importance.
(3) Each trial subject received a code number consisting of 3 figures, the first showing whether he had received chess instruction (1 = S; 0 = S), the second related to the class (1 = 6A, 2 = 6B), and the third the sequence number in the class.
(4) The meaning of these figures becomes clear in 3, Scoring of the results.
(5) It was not desired to give names.
(6) The weights are thus put into small bags, each of them showing a letter.

Test director: Precisely so. And I can tell you that all the weights are as heavy as each other. Keep this in mind. Can you now tell me something on the state of this balance?
Trial subject: This is as high as that (pointing to the 2 scales).
Test director: Exactly. We thus see that the left scale hangs at the same height as the right scale. Can you find other words with which to express the state of our balance?
Trial subject: Our balance is in equilibrium.
Test director: Very true, Luc, our balance is now in equilibrium. Now take a good look at what I am doing. I am taking 2 weights, A and B, and I lay them on the left scale. I also take weight C and place it on the right scale. What takes place, Luc?
Trial subject: The balance dips along the left side.
Test director: Why is this so?
Trial subject: Because you have placed 2 weights here but only one weight there. And you said that the weights were equal, and therefore this scale weighs more.
Test director: Exactly so. Would you know how to now put the balance back in equilibrium?
Trial subject: (takes a weight and puts it on the right scale)
Test director: What have you done ?
Trial subject: I put a weight on the other side, and then there are two weights on each side.
Test director: What do you see now?
Trial subject: Our balance is back in equilibrium.
Test director: Why is this so?
Trial subject: Because just as much weight lies on each scale.
Test director: Good. I am removing the weight that you placed on one side. Our balance is again out of equilibrium. Can you now put it back in equilibrium in another way?
Trial subject: Take one weight away from the left scale.
Test director: Yes, now do so.
Trial subject: It is the same as the one I took off. They all weigh the same.
Test director: Yes. What do you now see about our balance?
Trial subject: It is back in equilibrium.
Test director: How do you know that?
Trial subject: The two scales hang at the same height.
Test director: Good. We will put the weight back. I will now ask you whether there is still another way to bring our balance into equilibrium?
Trial subject: There are two here and one there.
Test director: Yes. All the weights may be removed. Are you able to find some other way to bring this balance back into equilibrium?
Trial subject: (looks at the balance for some moments; after some thought): May I displace this? (he points to the top of the cord from which the right scale is suspended on the right arm).
Test director: Do so. ... What are you doing?
Trial subject: Hanging the right scale elsewhere.
Test director: Why are you doing that?
Trial subject: I believe it will then weigh more.

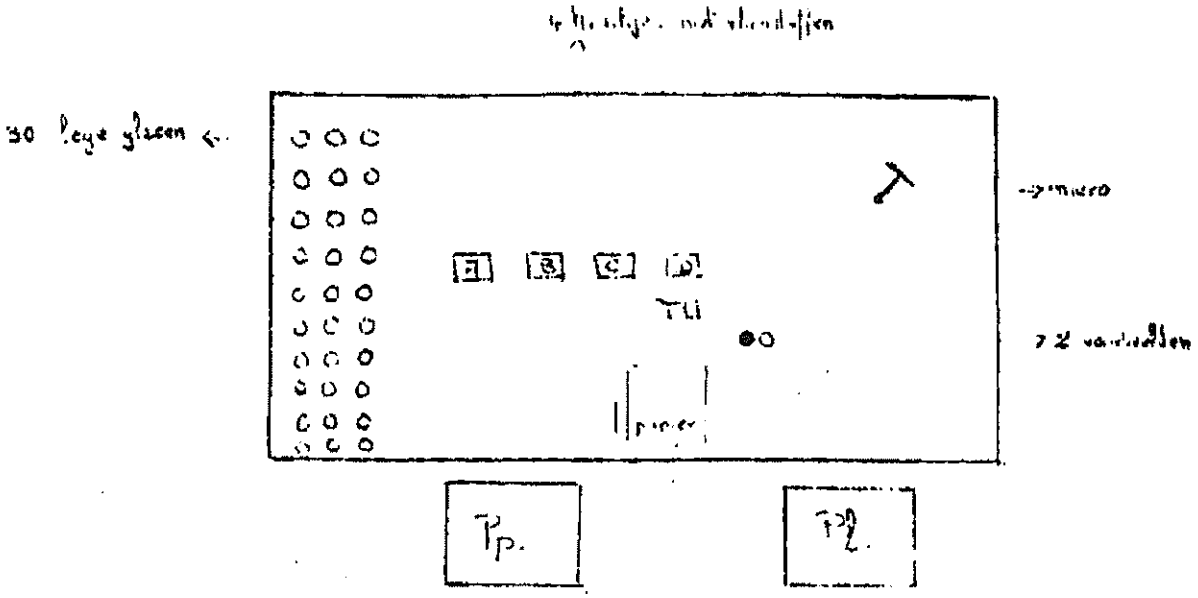
Test director: With what result?
Trial subject: The scale will dip down.
Test director: What will then be heavier?
Trial subject: ...(no answer)
Test director: What have you now actually done?
Trial subject: I have lengthened the right arm.
Test director: Precisely so. And what do you now see?
Trial subject: The more I extend the right arm, the more the scale drops.
Test director: Exactly. But now the balance is again not in equilibrium, it now dips on the right side. Can you put it back into equilibrium?
Trial subject: (displaces the right scalea few openings back toward the left, and after 2 trials he finds the correct opening).
Test director: How is our balance now back?
Trial subject: It is back in equilibrium.
Test director: I will put everything back as it was at the beginning, and I will ask you if you see another way in which to bring our balance back into equilibrium.
Trial subject: Shorten the other arm.
Test director: Good, Luc. Do so now.
Trial subject: It is a little too much (laughs once)(After a second attempt, he finds the correct opening for hanging up the scale).
Test director: What do you see now?
Trial subject: The balance is back in equilibrium.
Test director: Why?
Trial subject: I shortened the left arm, and for that reason the scale went upward. They are now again hanging level.
Test director: Can you now tell me the significance of your shortening or lengthening the arm? First think carefully before replying.
Trial subject: ... When I shortened the arm, the scale went upward, and when I lengthened it the scale went down.
Test director: Is this always the case?
Trial subject: ... Yes.

The last remark clearly shows a deficiency on the part of the trial subject. He still regards the situation too much in the light of an immediate proof. The requirement that the weight remains constant during the changing of the length of the arm did not appear here.

e. Definitive taking of the liquid test

Here, too, we present an example in order to illustrate the way this test is given.
Here, too, we take a good trial subject in order to make the course of the test clearer and to illustrate it until the final stage.

Trial subject: 121
Birth date: 1/16/64 - age 12 years 3 months
Test given on Friday April 16, 1976 from 8:30 a.m. to 9:25 a.m.
Duration: 55 minutes.
Result: score of the balance test: 4
score of the liquid test: 5



(glossary to figure on p. 54 of original)

"4 kannetjes med vloistoffen"	= 4 bottles with liquids
"30 lege glazen"	= 30 empty glasses
"micro"	= microphone for recorder
"2 voorbeelden"	= 2 examples
"papier"	= paper
"Pp"	= trial subject
"Pl"	= test director

Test director: That was good, Jan. (1) Now come to the table here. look at what we have here.
Trial subject: Glasses. Two glasses are filled, and one glass is filled more than the other.
Four glasses (laughs once because he does not find the correct word)
Test director: Let us call them bottles.
Trial subject: A is filled more than B, (2) B is about the same as C and is also about the same as D. (3)
Test director: Do you see something else on the table?
Trial subject: A drop counter with 1 on it.(4)
A sheet of paper. A number of empty glasses. A pencil. And a "micro" (laughs once).
Test director: Precisely. Now listen carefully. There are 4 differe liquids in these 4 bottles. I have designated each of

(1) Here, too, names are not given.
(2) On one occasion the bottles were given 4 letters as designations and another time 4 numerals. This was changed every day.
(3) In fact, the quantity of liquid was immaterial.
(4) This small dropper was converted into a drop counter.

Test director: Yes, let us call the color yellowish red, agreed? I will let this staud here. (The test director places the glass with the colored liquid at the right on the table in view of the trial subject.) I would like to ask you how you could now achieve the same yellowish red color. You can use liquids A, B, C, D and 1, and you also have a paper and pencil at your disposal. A number of glasses are also starding there for possible tests.

(The trial subject takes one glass, pours B into it and after that 1).

Test director: I would like you to tell me what you are doing each time and why you are doing it. Agreed?

Trial subject: I poured B into a glass and added 1.

Test director: And what do you see?

Trial subject: That nothing has happened.
(several moments of quiet; the trial subject looks, but no color has as yet developed).

Trial subject: I will take another glass. (Trial subject takes another empty glass and pours C into it).

Test director: You are doing more.

Trial subject: I am pouring C in and in addition 1. But nothing is happening. (The trial subject again looks at the failure to develop color and at the earlier glass).

Trial subject: I will now try once with D.

Test director: Tell what you are doing.

Trial subject: I am now pouring 1 into D. And ... again nothing ... (The trial subject again looks for several seconds.) I have not yet tested A. (Takes a new glass and pours A into it and after that 1).

Trial subject: A with 1 also does not give anything... May I also pour two of the liquids in succession and then add 1?

Test director: You may make use of all the liquids.

Trial subject: (Takes a new glass.) I am going to pour A and B together and then add 1.... Again nothing.

Test director: Do you still know what you have poured in all cases?

Trial subject: Yes, I have mixed A with 1, B with 1, C with 1, and D with 1. And here now also A and B with 1. (The trial subject points to the mixtures obtained.) I am now going to test A and C and thereby 1... Ha, ha, it becomes colored. It is A, C and 1.

Test director: A, C and 1 thus provides the color. Is that the only mixture that gives a color?

Trial subject: I don't know that; I would have to make more tests. (Takes a new glass.) I can now pour A and D together and then add 1... It does not give any color. (He is looking and also regards all the mixtures obtained.) May I write it down?

Test director: You may use everything you find lying on the table.

Trial subject: (laughs once and writes: $A+1 \neq 1$).

Test director: Why do you put that sign afterward?

Trial subject: Because it did not give any color.

Test director: Ah, ha. (The trial subject furthermore writes down all the possibilities tried.)

Trial subject: I can now also pour B together with C and B with D.
Test director: Will that give a color?
Trial subject: I don't know. I will have to test that. (The trial subject pours B and C together and pours in 1).
Trial subject: B and C and 1 do not give a color. (The trial subject takes a new glass and tests B, D and 1).
Trial subject: Also nothing.
Test director: Have you now tested everything? (The trial subject now looks at his sheet.)
Trial subject: No, not yet C and D.
Test director: Then do so. (The trial subject pours C and D together with 1.)
Trial subject: Also no color.
Test director: Have you now tested everything?
Trial subject: ... May I also pour 4 liquids together?
Test director: You may use everything I mentioned. (The trial subject takes a glass and pours A,B C and then 1).
Trial subject: Ha, ah, this also gives a color. A, B C with 1. I will mark a small cross.
The trial subject then also tested ABD, ACD, BCD, always together with 1, and noted that he failed to obtain a color every time.
Trial subject: I can now also put them all together.
Test director: Do so.
Trial subject: ...No color. (Because the trial subject in all cases poured in 1 as the last liquid, he was not yet able to detect the decolorant effect of liquid D.)
Test director: What has given the yellowish red color?
Trial subject: A plus C plus 1 and A plus B plus C plus 1.
Test director: Can you tell me what liquid B could be?
Trial subject: B? ... B also gives the color like A and C together.
Test director: Is B necessary for obtaining the color?
Trial subject: No, because A and C with 1 also gives a color.
Test director: Then what may B be?
Trial subject: Ordinary water, perhaps.
Test director: Just so, Jan. Can you also tell me what the other liquid might be?
Trial subject: (takes bottle A and smells it.) ...
Test director: Is this A necessary for the color?
Trial subject: Yes.
Test director: What can it be?
Trial subject: Some kind of colorant ...
Test director: It is indeed a substance which can impart a color. Does A always impart a color?
Trial subject: (Looks at his sheet). No, only when it is with B and C and 1 or without B, only with C and 1.
Test director: And what does liquid D do?
Trial subject: It does not give any color.
Test director: Is it also water?
Trial subject: No, as otherwise ACD and 1 also should color, and that does not color.
Test director: AC and 1 gives a color and ACD and 1 does not give a color, so what does D do?
Trial subject: ... (Looks at D and at colored liquid AC1). May I add D?

Test director: Do so.
Trial subject: Hm, ah ha, this is peculiar.
Test director: What do you see?
Trial subject: When I add D, the color goes away.

3. Scoring of results

a. Balance test

Inhelder and Piaget distinguish the following stages on the way to a good complete solution of the balance test.

Stage 1: Absence of differentiation between the action itself and the exterior process (IA), then connection of intuitions in the direction of compensation for the weights (IB)

In this first stage, occurring at the age of about 7, Inhelder and Piaget present the example of:
Gas (5 years 9 months): "He could put it on one side or the other; he takes one which in fact has a similar envelope cover but is of quite different weight. This does not work; perhaps there is a little too much weight there." (1) (Inhelder and Piaget 1970, p. 147)

The child thus subsequently understands that one weight must be along each side in order to have an equilibrium, and he also knows that these weights must be about equal. However, he is not yet able to systematically realize this phenomenon. The child thus comes to adding and removing weight, but without precise evenness; there are successive corrections, thus regulations, and not yet operations which are precisely reversible.

Stage 2: IIA: Concrete operations on the weights or distances but without systematic coordination among them.

Corresponding to the concrete operational stage, Inhelder and Piaget present the following example in this first substage:

Nem (7 years 4 months): empirically found that C at the left, at distance 10, balances E at the right, at distance 5. He was requested to place C on the right and E on the left, but he did not get to reverse the distance ratios. Following trials, he cried: 'Ah! It is necessary to do the same thing as before, but oppositely!" (Inhelder and Piaget 1970, p. 148)

In this period, the child is thus able to arrange weights in classes without distribution and achieving equality along both sides. He can add weights in a reversible way and correctly compare. The child can thus realize the temporary nature of the equality and inequality relations of weights. All of these operations return in another form in the comparing of distances of the arms.

Stage 3: IIB: Inverse correspondence of weights and distances

(1) In this period, dolls were used as weights.

In this second substage of concrete operational thought, the test is solved better in the sense that in the previous stage the child, in the presence of 2 weights which were not hanging in balance, mainly worked with additions and removals of weight (= some application of identity operation and inversion operation). The child rarely came upon balancing the balance by displacing the plates. In stage IIB, the child seeks equilibrium by displacing a weight in a certain direction on the hypothesis that the same object weighs more the farther away it hangs and less when it hangs closer in (= also able to apply reciprocal operation and correlation operation).

Summary: ability to apply the 4 operations of the INRC group but not yet the ability to develop them together into one system.

Stages 4-5: III: Discovery and explanation of the law

In this third stage, IIIA at the start, a metric relation already exists; a weight which is 2 times less must be suspended twice as far away in order for the scales to hang at the same height. In IIIB, the child also speaks clearly in the sense of, "A system of compensations among height, length, and weight is involved." The child does not remain in a given test situation, he proceeds to generalize.
Characteristic of this stage is thus a fullfledged handling of the INRC group with distinction of operations among themselves.

Example: Trial subject 123:

Test director: What have you done now?
Trial subject: I have shortened the left arm.
Test director: How is it that you so rapidly know in which hole the scale must hang?
Trial subject: The right scale hangs 5 holes from the fulcrum and 2 weights lie on it. But here there is only one weight, and I therefore put it on hole 10.
Test director: Ah, ah. Can you tell me what the relationship is?
Trial subject: A relationship exists between the number of weights and the number of holes on the arm.
Test director: What do you mean?
Trial subject: Two weights in hole 5 weigh as much as one weight in hole 10, which is thus twice as far.
Test director: Very good, K.

b. Liquid test

Here, too, each trial subject receives a grade from 1 to 5, approximately corresponding to the following stage features:

Stage 1 (I): Empirical associations and precausal explanations

The trial subject at a preoperational thought level is only capable of random combinations of 2 liquids and remains with precausal explanations such as, "Hey, this becomes a siyup."

Stage 2 (IIA): multiplications of factors by "g"

Here the trial subjects successively test A, B, C, and D with g (in our test, this liquid was called 1), but they did not progress beyond the addition of 2 liquids.
To the question of whether no other possibilities exist, the trial subjects reply, "That's all - there is no color."

Piaget states: "No combinative operation properly speaking exists as yet, but only correspondences and seriations, i.e., combinations of the first power in relation to fixed features." (Inhelder and Piaget 1970, p. 101)

Stage 3 (IIB): Multiplicative operations, with empirical beginnings of n x n combinations

The reactions of level IIB are analogous to those of the foregoing level, but with a sensitive progress which is the beginning of n x n combinations. However, it is not simple empirical random attempts which are involved but rather that the child clearly discovers the system.

Alb (10 years 4 months) begins with 1 x 2 x 3 x 4 x g and then changes the order: 3 x 1 x 4 x 2 x g. This is different, because the first time I was going in sequence but not now. (He does 2 x 4 x 1 x 3 x g). Nothing happens (he then makes some permutations at random and then gives up). Is it necessary to take them all? No, he can take 2 or 3 of them if he wants (he tests unsystematically and accidentally comes out correctly. (Inhelder and Piaget 1970, p. 103)

Stage 4 (IIIA): Formation of systematic combinations n x n.

With the appearance of the formal operational thought level, we see 2 novel features, namely a systematic method in the use of the different n x n combinations and the understanding that the color is to be attributed to a pair of liquids (and not so much to one liquid).
After a good solution has been found, the child will further investigate whether a second combination will also produce the color.

Stage 5 (IIIB): Balancing the system

Only a difference in degree exists between this stage and the foregoing one. The only new or better feature is that the combining method is developed still more systematically here. (Example: see Trial subject 121, pp. 39-43)

b. PMS tests

As was the case every year, the Department of Studies and Occupational Orientation of Eeklo also gave a set of tests to all pupils in the sixth grade in the course of March 1976 with a view to recommendations in connection with the possible study aptitudes and prospects of the pupils.

The results of these tests were considered especially useful to us, as the tests were conducted by a test director who could be considered neutral in the sense that he did not know which children had received chess instruction and which had not. Considering the standardization and collective nature of the tests, the results could certainly be taken seriously. A possible influencing by the chess instruction could then also take place in this scoring.

The set of tests taken related to speech tests and school tests. Within the framework of our investigation, it was useful and possible for us to take the results of the following subtests into consideration.

Subtest - filling in sentences:

This test comes from the humanities set of Swinnen and Nuttin. The subtest includes the filling in of 6 sentences. Four or five words were missing in each sentence. A number of possible fill-in words were given. The trial subjects were requested to select the most suitable word.

Subtest - DGB word assessment: (1)

A number of sentences were presented, each with one work in capital letters. Four other words were located beneath it. The pupils were requested to select the word most closely similar in meaning to the word in capital letters.

Subtest - DGB relations:

Series of different words were available in each case. Each series consisted of 5 words, one of which was of less suitable fitness in the series. The trial subjects were requested to mark down that word on the pertinent answer sheet.

Subtest - DGB problems:

It was not required to solve the problems, and thus no effort was to be made to find the answer. The investigation was mainly on whether the trial subject had a good understanding of the problem and whether he had a good understanding of what course to follow to achieve a good solution.

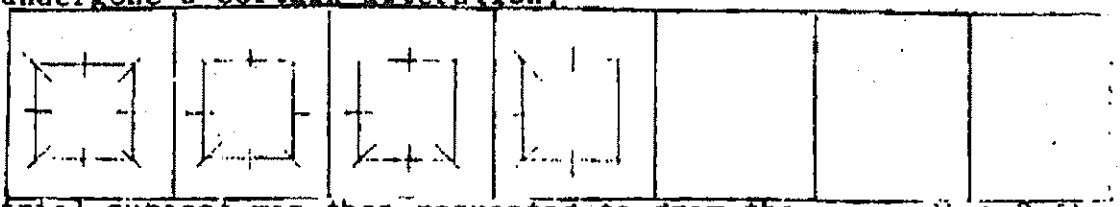
Subtest - DGB calculations:

Here, for example, the trial subject was asked to look for the difference between two sums. He was told in this connection that it was not necessary to make the additions themselves; when the trial subject considered the problems carefully, he could easily himself observe the difference between the 2 results. (Coetsier 1964).

(1) D.G.B. = differential capability battery (Coetsier 1964)

Subtest - GDF (Gedeon de Froidmont)

This subtest consisted of 35 series of figures, each of which had undergone a certain alteration.



The trial subject was then requested to draw the succeeding 3 figures.

In conclusion, we also took the total PMS score into consideration. This is based on the DGB tests, the school tests, and the Gedeon test.
Each test was scored by the Department of Studies and Occupational Orientation with standard units going from 1 up to and including 9, with the middle range at 4,5 and 6. The total score was also expressed in this way. The standard unit scores were designed in order to be able to process as much test information as possible in one column on the punch card. The standard unit scores did not exactly correspond to a given crude score but represented a range of ½ unit. The middle of the fifth standard unit score forms the average of the distribution.
The adaptation of the standard unit score to the different distribution segments takes place according to the following table, based on a normal distribution:

4%	7%	12%	17%	20%	17%	12%	7%	4%	
1	22	3	4	5	6	7	8	9	standard unit score

(Drenth 1971, p. 154)

c. School results

In spite of the fact that these results were obtained by the teachers, who could not be regarded as neutral test directors within the framework of our trial (they knew which children were receiving chess instruction and which were not), we nevertheless also gave consideration to these results.

A primary reason for this was that the dropout of 3 pupils from our control group made the 2 groups no longer equal, and we therefore had to introduce corrections on the basis of the school results at the end of the fourth scholastic year (thus just before the beginning of the chess instruction).

As these school results were nevertheless available and an evolution could certainly be derived from them on how conditions were at the end of the fifth school year in comparison with the end of the sixth school year, we considered them important enough to also take them into consideration.

The school results of the end of the fourth, fifth and sixth scholastic years were therefore also worked up. In all cases, the

the final yearly results obtained after the June examination period were involved. The results of performances during the year were not considered. We used the percentage results.
Originally, however, the results were quoted based on 400 points. The grading from the sixth scholastic year, for example, were thus obtained by: native language: 160 (speech and spelling: 50; dictation: 20, reading: 40; composition: 40; listening comprehension: 10).
Arithmetic: 120 points (elementary geometry: 20; measuring calculations: 20; figure calculating: 20; fractions: 10; mental arithmetic: 20; problems: 30).
Miscellaneous: 30:natural science: 30; French: 30.

III. ANALYSIS OF THE TEST RESULTS

Introduction

All the investigation results were entered on punch cards at the outset with a view to computer processing. Each data card corresponded to the data from one trial subject. Fourteen data items were entered on each of the 37 cards. (1)

1. Number consisting of 3 figures for the trial subject (see 3a, 2c)
2. Score of the balance test (1 figure of 1 true mean from 5, according to the level)
3. Score of the liquid test (1 figure of 1 true mean from 5, according to the level)
4. Score on the PMS test, DGB word assessment (1 figure of 1 true mean from 9)
5. Score on the PMS test, DGB relations (1 figure of 1 true mean from
6. Score on the PMS test, DGB problems (1 figure of 1 true mean from 9)
7. Score on the PMS test, DGB figure calculations (1 figure of 1 true mean from 9)
8. Score on the PMS test, subtest sentences (1 figure of 1 true mean from 9)
9. Score on the PMS test, subtest Gedeon (1 figure of 1 true mean from 9)
10. Score: PMS general total (1 figure of 1 true mean from 9)
11. School results of the 4th grade, expressed in percent (2 figures)
12. School results of the 5th grade, expressed in percent (2figures)
13. School results of the 6th grade, expressed in percent (2 figures)
14. Chess points (2 figures, 00 (control group) up to 21 (maximum)

These data cards with the pertinent control cards were processed in a bivalent variant analysis with the collaboration of the Laboratory for Experimental, Differential and Genetic Psychologic at Gent.
It was first intended to process the results with the Mann-Withney U-test, but this idea was later discarded as it was seen that the dropping out of 3 pupils from the control group had resulted in a difference between the 2 groups (trial group and control group) in favor of the trial group in the average of the school results in the fourth grade.
We therefore used an ANOVA computer program with adaptation of the

(1) As has already been mentioned, 3 pupils from the control group left the school.

Cooley-Lohnes program for factorial ANOVA with covariant adaptation. (Mervielde 1972)
This is a program for parametric univariant analysis, a bivalent variant analysis with covariant adaptation, whereby a possibility thus existed for correcting differences.
In our investigation, corrections were made for the differences in the school results of the fourth grade, so that both groups (control and trial groups) could be considered equivalent with respect to their scholastic results at the beginning of the chess instruction.

A. Comparison of the trial group and the control group

1. Piaget balance test

Both in connection with this test and for the following results, we obtained 2 effects in this program, called "I-means" and "J-means."

The I effect relates to the comparison between chessplayers and non-chessplayers. I 1 is the chess group. I 2 is the non-chess-playing group or the control group.

The J effect (which did not in fact greatly relate to our investigation goal) gives a possible difference between class 1 and class 2. J 1 is class 5B or 6A (the same pupils). J 2 is class 5A or 6B.

	I 1	I 2		F	
J 1	3,27	2,57	2,96	2.87	I-effect
J 2	3,45	3,02	3,25	.89	J-effect
Tot.:	3,36	2,81	3,11	.31	I x J effect

We see that the average level (considering all pupils) is 3,11. In other words, we can conclude on the basis of the balance test that the pupils (age 11 years 10 months) on average were at an equilibrium level of the concrete operational thought level (level 3 = IIB).
This corresponds to the age standards given by Piaget. From our table above, we see that the pupils from class 6A were not at that stage on average (2,96), whereas the pupils from 6B had an average level of 3,25. The lower performances of 6A in comparison with 6B in this balance test appear peculiar, since in the following test 6B usually gave poorer performances than 6A.
We can inquire whether a number of pupils in 6B might have done well because the test concerned work with a balance. The pupils from 6A always came first in the test director's sequence.
Since the tests were given during the vacation period, a time in which the pupils had less contact with each other, we do not assume that pupils from 6A told the solution method for the balance test to the pupils from 6B. There was an average difference of 2 to 3 days in the taking of the tests.

Another explanation might be sought in the fact that a balance with weights was standing at one of the window benches in class 6B. It might also have been possible that these children had worked with a balance more than the pupils from 6A, who might perhaps only sporadically have seen this balance during one lesson. However, it does not seem to us that this supposition can explain the difference reported, as a balance was involved which did not permit any lengthening or shortening of the arms. Knowledge of the relations between height of the scales, number of weights, and length of the arms thus presumably does not come into consideration.

When we regard the F values from the foregoing table, we do not see any significant difference. Our significance values were as follows (between 1 and 33 degrees of freedom):

F 2,88 ___ significant at level ,10
F 4,17 ___ significant at level ,05
F 7,56 ___ significant at level ,01

The I effect (difference between chessplayers and nonchessplayers) at 0,01 is too small to be significant at level .10.

2. Piaget liquid test

	I 1	I 2		F	
J 1	3,38	3,31	3,35	.43	I-effect
J 2	3,48	3,21	3,35	.00	J-effect
Tot.:	3,43	3,25	3,35	.17	I x J

First of all, we should mention that in all cases adjusted means were involved, adapted to the differences which existed at the end of the fourth scholastic year between the 2 groups (trial group and control group).
The average performance level of all trial subjects was 3.35, which according to Piaget's theory corresponded to the equilibrium level of concrete operational thought (level IIB) and was even somewhat farther in a beginning phase of the disequilibrium level of the formal operational stage.
On average, the chessplayers from 6B did best (3,48). However, the differences seem to be small and certainly cannot be considered significant.
Our consideration that chess instruction might promote the good development of combinative thought thus does not appear to be correct. It was just as easy or difficult for the nonchessplayers (approximately) to prepare a combination as for the chessplayers. On internal analysis of the trial group, however, we found that a low correlation existed between the good preparation of a combination and chess strength. (see IIIB).

3. Subtest DGB word assessment

	I 1	I 2		F	
J 1	3,95	4,54	4,21	.82	I-effect
J 2	4,94	3,43	4,22	.00	J-effect
				4.44	I x J
Tot.:	4,44	3,95	4,22		

Expressed in standard score units, the average for the trial subjects was 4.22. This is averaged toward the low side. The best group were the chessplayers from 6B, who had almost 5 in standard score units. The higher grade of nonchessplayers from class 6A in comparison with the chessplayers from class 6A is remarkable. We found that in most subtests the chess group scored somewhat higher than the nonchessplayers. In the DGB word assessment tests and the sentences subtest, however, the reverse situation existed in class 6A.
However, the I-effect remains in favor of the chess group, considering the greater difference in the second class, where the chess group had 4.94 on average and the nonchessplayers only 3.43.
However, the relating F-value is not significant (.82).
It is also not possible to speak of a J-effect in this subtest.
An unexplainable interaction effect of 4.44 is quite significant at level .05.

4. Subtest DGB relations

	I 1	I 2		F	W^2	
J 1	4,96	4,64	4,82	3.17	.05	I-effec
J 2	4,58	3,05	3,86	3.58	.06	J-effec
				1.21	.01	I x J
Tot.:	4,77	3,80	4,32			

On average, all pupils did somewhat better on this subtest than in the foregoing test (4.32 in comparison with 4.22). The good performances of the chess group from the first class were remarkable in comparison with the weak performances scored by that subgroup in the foregoing test (from 3.95 to 4.96).
The lowest group is the nonchessplaying group from the second class.
With these 2 differences in comparison with the foregoing test, we indeed see a significant difference between chessplayers and nonchessplayers in these DGB relations. The level of significance is .10.
At first sight, the indication of a word which fits in less well in a series of 5 different words seems to have little relation to chess. The relations established in chess are more of a spatial than verbal nature. However, in this subtest the best choice is to be made in considering a given "problem," precisely as in chess the best countermove must be selected from a number of possible moves.

We also find a significant result between both classes at level .10 especially indicative of the weak performances of the nonchessplayers from the second class.
As we find significant differences, we also consider W^2, which is the percent explained variance. (1) This gives .05 in the I-effect. In other words, chessplaying compared with nonchessplaying explains 5% of the variance in the solution of the subtest of DGB relations. 95% of the variance thus cannot be attributed to chess. We also find an about similar phenomenon in connection with the J-effect.

(1) Variance: a degree of dispersion around the arithmetical mean.

5. Subtest DGB problems

	I 1	I 2	Tot.:	F	
J 1	5,16	4,77	4,98	.82	I-effect
J 2	4,65	4,20	4,44	1.47	J-effect
Tot.:	4,90	4,47	4,70	-.06	I x J

Here, too, on average all the trial subjects did somewhat better than in the foregoing tests with a total average of 4.70 in standard unit score. Similarly as in the foregoing subtest, the pupils from the chess group in 6A scored highest and the nonchessplayers from 6B the lowest (5.16 in comparison with 4.20). We obtained better results from the chess group in both the first and the second class, but the difference is not considered significant (F = .82).
There is also no significant difference between these 2 classes in this problem test.

A possible effect of chess instruction on this subtest would have surprised us, but here, too, we found that the chessplayers did somewhat better than the nonchessplayers.

6. Subtest DGB calculations

	I 1	I 2	Tot.:	F	w^2
J 1	5,26	5,02	5,15	.08	
J 2	4,39	4,37	4,38	3.26	.06
Tot.:	4,82	4,69	4,76	.05	

The average performance level again rose slightly (4.76).
Here, too, the best group was the trial group in 6A, whereas once again the control group from 6B gave less good results. The difference between chessplayers and nonchessplayers was not significant, but the difference between class 1 and class 2 was to the advantage of class 1 at level .10 (F 2.88).
In the case of this subtest as well, it appears that "normally" chess does not exert any influence on the good solving of a number of calculating efforts. The average scores in both 6A and in 6B were about the same when the trial and control groups were compared.

7. Sentences subtest

	I 1	I 2	Tot.:	F	w^2
J 1	4,40	4,79	4,47	1.17	
J 2	4,35	2,91	3,67	3.23	.05
Tot.:	4,38	3,79	4,11	3.22	.05

The total average performance level (4.11) was surpassed by the average of the chess group (4.38) but weakened by the nonchessplayers with an average of 3.79. The latter is especially to be attributed to the very weak performances of the nonchessplayers from the second class (2.91). On the other hand, the nonchessplayers from the first class themselves did better than the chess group from 6A (4.79 in comparison with 4.40).

Whereas the I-effect was not significant, we found a significant J-effect at level .10 (again to the advantage of the first class). Here, too, we interpret this nonsignificant difference between the trial group and the control group in the sentences subtest as about normal. The "silent" chessplayer will not learn so fast from his mental sport how to select the most suitable word from a number of given words for insertion into these sentences.

8. Gedeon subtest

	I 1	I 2	Tot.:	F	
J 1	5,52	4,74	5,17	2.10	I-effect
J 2	4,69	3,89	4,31	2.72	J-effect
Tot.:	5,10	4,29	4,73	.15	I x J

Once again, it was remarkable how high the chess group from the first class scored in comparison with the nonchessplayers from the second class (a difference of 5.52 - 3.89 = 1.63!)
The total average difference between chessplayers and nonchessplayers amounted to (5.10 - 4.29) 0.81, and was not considered significant with an F value of 2.10. The class difference also was insignificant. Nevertheless, here too we can report that there was an advantage for the chess group, which turned in a better result in the following total score.

9. Total score of the PMS tests

	I 1	I 2	Tot:	F	W^2	
J 1	5,01	4,63	4,84	3,97	.07	I-effect
J 2	4,78	3,90	4,36	2.50	.04	J-effect
Tot.:	4,90	4,24	4,59	.46		I x J

These adjusted means show a significant difference between the trial group and the control group in favor of the former. The significance level lies between .10 (F = 2,88) and .05 (F = 4,17). This significant difference was to be expected in this total score, considering the earlier smaller differences.
The difference between 6A and 6B does not seem significant. The F-value of the interaction effect is too low to be considered significant.
With W^2 (percent explained variance), we see that chess vs. nonchess explains 7% of the variance in the total scores of the PMS tests.

10. School results from the fifth scholastic year

	I 1	I2	Tot:	F	W^2
J 1	65,60	61,70	63,87	8.23	.16
J 2	63,84	57,77	60,97	3.08	.05
Tot.:	64,72	59,62	62,38	.12	

A remarkably great significant difference (F = 8.23) was found at level .01 between the trial group and the control group to the advantage of the chessplayers. In other words, following 5 months of chess instruction (from January to June 1975), the chess group seemed to obtain significantly better scholastic results than the nonchessplaying group.
The question can thereby be raised of what the influence of the teacherswas? Did they knowingly or subconsciously give the children who received chess instruction more points? Or was it indeed a fact that pupils who were enthusiastic about the fact that they were receiving chess instruction (and others were not) did their best to a greater extent? Or did the chess instruction, which mainly involved theoretical lessons during the first 5 months, actually exert a stimulating effect on the development of intelligence and attitude formation?

11. School_results_from_the_sixth_scholastic_year

	I 1	I 2	Tot:	F	w^2
J 1	67,39	61,19	64,64	6.15	.10
J 2	59,52	52,93	56,40	10.93	.20
Tot.:	63,45	56,82	60,41	.51	

We also see a significant difference between the 2 groups for the scholastic results from the sixth year. The chessplayers gave significantly better results at level .05.
In comparison with the F-value of the school results of the fifth scholastic year, the difference between chessplayers and nonchessplayers now seems to have regressed. We expected that a still greater difference would be "normal," considering that the chessplayers had reached a still higher chess level one year later, but we found that the difference had decreased somewhat.
It could be inquired whether a habituation to chess was manifested, whereby transfer possibilities to school results decreased? Or was it precisely a higher interest in chess on the part of the pupils, who had now reached a higher chess level expressed now in playing as many games as possible, which consumed time and energy at the expense and to the disadvantage of schoolwork?

It was also remarkable that, in the school results of the fifth scholastic year, the difference between the highest average of a group (chessplayers from 6A)(65.60) and the lowest average of a group (nonchessplayers of 6B)(57.77) was about 8%.
In the school results of the sixth scholastic year, this difference (67.39 - 52.93) was between 14 and 15%! This greater difference can probably be explained together with the fall in general average by the fact that subjects such as physical education, drawing, and music were no longer considered in the school results of the sixth scholastic year.

It was in precisely these subjects that the poorer pupils could still obtain somewhat better results (also see 3c).

The difference between both classes was very great (F = 10.93!). This significant difference at level .01 is presumably to be attributed to a different grading of examination results from one teacher to the next. The variance can be 20% explained by the difference in classes, whereas the difference between chessplaying and not playing chess explains 10% of the score variance.

B. Internal analysis of the trial group

Until now, we were comparing the post-test results of the chess group in relation to the nonchessplaying group. The problem now also arises of whether, within the trial group, the ability to play chess well or not was in relation to the results of Piaget's tests, the PMS tests, or the school results. The question also remains of how these tests relate among themselves.

A computer program was used for this purpose for univariant parametric analysis: CORR Fortran IV program for correlation analysis. (Mervielde 1971)

With 20 degrees of freedom, the significance values were:

R = .36 p = .10
R = .42 p = .05
R = .54 p = .01

CORRELATION MATRIX OF VARIABLES FOR CHILDREN OF 11

CORMAT SECTION 1

ROW	2 Bal.	3 Liq.	4 Word	5 Rel.	6 Prob.	7 Calc.	8 Sent.	9 Ged.	10 PMS	11 4th Yr.	12 5th Yr.	13 6th Yr.
2	1.00	.49	.23	.19	.40	.15	.34	.19	.24	.04	.11	.12
3	.49	1.00	.15	.36	.59	.20	.34	.41	.45	.45	.40	.33
4	.23	.15	1.00	.73	.66	.69	.76	.44	.76	.68	.75	.71
5	.19	.36	.73	1.00	.81	.69	.73	.69	.87	.69	.79	.80
6	.40	.59	.66	.81	1.00	.70	.64	.65	.84	.72	.77	.78
7	.15	.20	.69	.69	.70	1.00	.77	.63	.91	.69	.80	.80
8	.34	.34	.76	.73	.64	.77	1.00	.51	.81	.60	.77	.77
9	.19	.41	.44	.69	.65	.63	.51	1.00	.81	.59	.64	.60
10	.24	.45	.76	.87	.84	.91	.81	.81	1.00	.81	.92	.90
11	.04	.45	.68	.69	.72	.69	.60	.59	.81	1.00	.94	.87
12	.11	.40	.75	.79	.77	.80	.77	.64	.92	.94	1.00	.97
13	.12	.33	.71	.80	.78	.80	.77	.60	.90	.87	.97	1.00
14	.33	.62	.34	.52	.57	.48	.42	.59	.57	.53	.49	.39

CORMAT SECTION 2

ROW	14 Chess
2 Bal.	.33
3 Liq.	.62
4 Word	.34
5 Rel.	.52
6 Prob.	.57
7 Calc.	.48
8 Sent.	.42
9 Ged.	.59
10 PMS	.57
11 4th	.53
12 5th	.49
13 6th	.39
14 Chess	1.00

KEY:
2 Piaget balance test
3 Piaget's liquid test
4 DGE word assessment subtest
5 DGh relations subtest
6 DGh problems subtest
7 DGh calculations subtest
8 sentences subtest
9 Gedeon subtest
10 general PMS total
11 [illegible]
12 school results 4th year
13 school results 5th year
14 chess points

It was a remarkable finding that the correlation between the results of the balance test and the liquid test was not so high. A Piaget explanation for this might be that of a horizontal displacement (see p. 22 of original).
The results from both the balance test and the liquid test correlate very poorly with the other test results.
We found a remarkably strong correlation between the school results and the PMS total (.81 with the 4th school year, .92 with the 5th school year, and .90 with the 6th year). This is not to be considered so surprising, as the standardization of the PMS tests takes place precisely on the basis of school results.

Chess strength appears to correlate best with the results of the liquid test (.62). This strengthens our supposition that a chess-player plays more strongly the better he builds combinations, and by means of the dissociation of factors he comes to a clear overview of all influencing factors.
Schess correlates quite highly (.59) with the results of the Gedeon test as well, a test which makes use of spatial concepts.

Whereas the chess points still correlate with .49 in comparison with the school results at the end of the fifth scholastic year, this figure fell to .39 at the end of the sixth year. This finding corresponds to the data reported earlier on the intergroup comparison, whereby it seems that the influence of chess on the scholastic results was higher at about the end of the fifth year than at the end of the sixth year.

IV. SUMMARY AND CONCLUSION

Starting from the problem of whether chess instruction might not exert a favorable stimulating effect on the formation of formal operational thought levels, we set up a "post-test only control group." In this trial design, we divided a group of 40 pupils from classes 5A and 5B of elementary education from the municipal boys' school at Assenede at random into a trial group and a control group of 20 boys each, average age 10.6 years old.

The trial group was given a total of 42 chess lessons of 1 hour each by the "Youth Chess" method of B. Withuis from January 1975 to May 1976. These lessons were given each week on Friday afternoon after lessons from 3:30 to 4:30 p.m. The pupils from the control group were allowed to go home, so that their alternative activity certainly did not consist of systematic instruction.

The balance test of Piaget was first taken as a post-test, whereby the formation of the INRC group is required. A second test of Piaget's, the liquid test, was also taken and showed the possible formation of a combinative formation. Both tests were given by a "neutral" test leader and under "neutral" conditions, so that the participants could not determine any relation between the chess instruction and the testing. Preliminary tests were made to show possibilities with these Piaget tests for both the investigative method and the test leaders. Both tests were scored with levels of 1 t/m 5 according to Piaget's cognitive theory as classified by Inhelder in analogous tests.

It was evident from the investigative results that the mean lies at the third level (IIB), which agrees with Piaget's opinion that children about 12 years old have the balance level of concrete operational thought.

Additional post-tests as well as school and PMS results were also taken into consideration because they were available, independentl of our study. From this standpoint, results between the trial and control groups were compared for a number of "speech tests" given and scored by the Service for Study and Vocational Orientation. The scholastic results for the 4th, 5th and 6th school years should thereby be able to provide supplemental information showing an "evolution" of possible advances of the chess group in comparison with the nonchess group.

Finally, a scoring of the chess strength of each subject in the trial group was determined. It was thus also possible to calculate correlations between the chess strength and other test results.

A double variant analysis with covariant adjustment on the basis of the scholastic results of the 4th school year was selected for the processing of the results. The results were thereby adjusted to differences between the trial and control groups.

With these adjusted means, we obtained significant differences between the 2 groups for:

school results of the 5th school year, significant at level 0.01;
school results of the 6th school year, significant at level 0.05;
DGB relationships subtest and PMS total, significant at level 0.10.

The results for the balance test were only 0.01, too little differentiating to be able to be considered significant at level 0.10. The effects appeared to be rather small for the other tests, although a small advantage was often found for the trial group. The incidental comparison between the 2 classes showed somewhat better results for the first class in comparison with the second.

Finally, it appeared from the internal analysis of the chess group that the chess-plaing strength showed the best correlation with the results of Piaget's liquid test, which calls on a combinative formation.

PART 4: GENERAL SUMMARY AND CONCLUSION

At the outset of our investigation, we already clearly set outselves the task of investigating the influence of chess on the course of cognitive development as described by Piaget. In addition, a possible influence on school results and on the results of two intelligence tests was also studied. These ideas were in part based on a number of (untested) statements often made in chess circles.

It was then also necessary to dwell on "playing chess" to a certain extent in the first part. After a description of the different types of chess playing, we pointed out that the study of chess in Belgium has been both qualitatively and quantitatively backward in comparison with other countries. However, progress has been made in recent years, chiefly due to the great increase in the category of youthful chessplayers. This group was mainly developed by giving instruction in chess in a number of secondary schools, later also in elementary schools, although it is true that in Belgium this took place outside lessons and only for interested students.

In a third part, we determined that, although about 100,000 books relating to chess have been published, only a small number of them have been concerned with psychological studies in connection with chess. No investigations and results exist on the possible influence of chess on cognitive development in the 10-to-12-year age group.

A further digression on the basic principles and phase classification of Jean Piaget was discussed in the second part. We consider them to be naturally and psychologically of particular importance as children develop new formal thought structures at about the end of the primary school age which clearly show qualitative differences in relation to concrete operational structures. Piaget considered the ability to adjust combinative formation and the INRC group to be the most important features of formal thinking.

Together with Inhelder, we then also attempted to demonstrate the existence of both thought structures in preadolescents on the basis of numerous test situations.
This development from the concrete to the formal operational thought level reaches an equilibrium at around age 14-15, according to Piaget. However, both the starting age and the age at which the equilibrium level of formal operations is reached are subject to environmental influences and thus vary from one individual to the next. Piaget does not exclude the possibility of advancing this age standard by a "stimulus-rich" environment (with chess instruction?).

The third part considered the development of an investigative design on the problem of whether formal operational thought could be advanced by giving chess instruction. As reported at the outset, the influence of chess on school grades and intelligence tests was investigated. The post-test-only control group plan, which makes use of the randomization principle and does not provide for any pretest, seemed to us to provide the greatest guarantees for both the internal and external validity of our investigation.
After determining the age, school, and sex for our total group, it was divided at random into a trial and a control group, each with 20 pupils.
A total of 42 chess lessons were given to the first group of these trial subjects from the fifth year at the Combined Lower boys' school at Assenede from January 1975 to May 1976 by the youth chess method of B. Withuis. These chess lessons were given after the normal class hours every Friday afternoon in the 5B classroom from 3:30 to 4:30 p.m. Whereas the pupils from the control group went home at that time, the other children undertook to attend these weekly chess lessons.
After the choice of the tests and the solution of the test director problem, the Piaget post-tests were given to each pupil during the Easter vacation from April 11 to April 16, 1976. A number of prior studies confirmed the value of both the investigative method and the test directors.

The Service for Study and Occupational Orientation at Eeklo collectively conducted test series for all pupils from the sixth scholastic year during the month of March 1976 as well as every year. These test results should be considered post-tests, together with the scholastic results of the fourth, fifth and sixth scholastic years.

A first analysis of the investigation results involves a comparison between the trial and control groups. This was accomplished with the aid of the ANOVA computer program, adaptation of Cooley-Lohnes program for factorial ANOVA with covariant adaptation, which made it possible to adapt the test results obtained for the departure of 3 pupils from the control group, who were transferred in the course of the sixth school year. The adjusted means thus obtained on the basis of the scholastic results of the fourth school year showed significant differences between the two groups in favor of the chessplayers:

- scholastic results of 5th school year, significant at .01 level
- scholastic results of 6th school year, significant at .05 level
- subtest D.G.B. relations and PMS total, significant at .10 level.

The results of the Piaget balance test were only 0.01 too little differentiated to be called significant at level .10. The effects seemed to be rather small for the other tests, although there was usually a small advantage in favor of the trial group.

Finally, a second internal analysis (only in the trial group) was calculated with the CORR Fortran IV computer program for parametric univariate analysis. This correlation analysis showed that chess strength correlated best with the results of the liquid test (.62). In other words, a chessplayer plays more strongly after he can develop a combination completely and correctly.

Considered generally, the rather great positive influence of chess on school results in both the fifth and sixth school years seems rather unexpected. However, we must take into consideration a possible influence on the teachers, who were aware of the trial and thus consciously or subconsciously could act favorably or unfavorably in their relations with the pupils.

On the other hand, the significant difference in the PMS total is substantially due to the chess influence, all the more as these results were obtained by means of collective test results given and graded by test directors who were unaware of which pupils belonged to the chess group and which to the nonchessplayers.

In conclusion, we wish to point out that this investigation related only to the cognitive effects of chess instruction. Other possible advantages (a healthy competitive feeling, ability to lose, readiness to persevere, rapid thinking, analysis and remedying errors, etc.) or disadvantages (chess energy at the expense of study or work output, etc.) were not considered in this investigation.

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