The Making of an Expert: What can we Learn from the Training of Chess Masters, Elite Athletes and Musicians?

by

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Basic Conceptions of Techne, Craft and Expertise

Knowledge about a specific field, such as shipbuilding

Produces something useful—a ship

Production is reliable

It can be certified by earlier successful products, such as ships

It can be taught

Homer
(some time 900 BC to 700BC)

(Roochnik, 1996, p. 20)
Going beyond the merely acceptable
Refined description of measurements of performance

From building
    a ship that floats in
        calm weather

Building a ship
    that can weather storms
    that serves for a long time
        without breaks and maintenance
    that is fast and controllable
Kleides of Athens,
a Sophist philosopher
of the 5th Century B.C.E

Protagoras
(ca. 490-420 BC)

Isocrates
(436–338 BC)

Stochastic forms of techne, craft, and expertise

Medicine -- doctors do not always heal their patients
Rhetoric -- speakers do not always win arguments
Traditional Ideas about Expertise

Importance of extended experience

Social definition of many forms of expertise

General education and mastery of theoretical knowledge
Acquiring Practical Skill

For the things we have to learn before we can do them, we learn by doing them, e.g. men become builders by building and lyre-players by playing the lyre; ..

Aristotle (Nicomachean Ethics, p. 29)
Recent books have featured findings from my colleagues and my own research. 

10,000 hour rule 
Deliberate practice
The Constraint of Access to Appropriate Experiences

Scarcity of patients with a given disease
- Experience of even a single case

Limited opportunities to administer medical treatments

Limited opportunities to observe differences in disease progression
Outline of My Presentation

I. If teaching was a domain of expertise, like Chess, how would expert performance be attained

II. Traditional learning of professional performance

III. Mechanisms, skills, and their acquisition through deliberate practice

IV. Objective measurement of performance

V. Optimizing training time

VI. Concluding thoughts on guiding the development of expert performance
Part I. If Teaching was a Domain of Expertise, like Chess, How is Expert Performance Attained

How did chess players attain their performance?

Benjamin Franklin learned to play chess from an acquaintance in 1733. He was one of the first chess players in America. Although he was an avid player, he reached a modest level of chess skill.
Our Knowledge about Learning and Skilled Performance is Limited

How good is a chess player or an individual in a domain of expertise?

--Self ratings
Self-Assessments on Relative Performance

How would you rate your own performance?

bottom 10%  below average  average  above average  top 10%

Professors  (94% above average)  Drivers  (80% above average)  Doctors  (Davies et al., 2006)
Rated Relevance for Improvement from Doing X on a scale from 1 to 7 (Charness, Krampe, & Mayr, 1996)

Active participation in chess tournaments

Playing chess games outside of chess tournaments

Serious analysis of positions alone
Rated Relevance for Improvement from Doing X on a scale from 1 to 7 (Charness, Krampe, & Mayr, 1996)

Active participation in chess tournaments 6.1

Playing chess games outside of chess tournaments 3.6

Serious analysis of positions alone 5.9
Effects and Dose-Response Relations to Practice Activities

Expert Performance

Gradual improvement in some specific aspect

... for a beginner
<table>
<thead>
<tr>
<th>Activity</th>
<th>Relevance</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active participation in chess tournaments</td>
<td>6.1</td>
<td>No correlation</td>
</tr>
<tr>
<td>Playing chess games outside of chess tournaments</td>
<td>3.6</td>
<td>Negative predictor</td>
</tr>
<tr>
<td>Serious analysis of positions alone</td>
<td>5.9</td>
<td>Positive correlation</td>
</tr>
</tbody>
</table>
Simulated Play Against World Class Players
Study published games by chess masters

Make predictions for each next move
Check if your prediction was correct, if not, study the chess position until you understand why the correct move was played
Practice Alone by Skill Group
Charness, Krampe & Mayr, 1995

The First 10 Yrs of Practice Alone

Mean Cumulative Hours

Year

Elo=1800
Elo = 2200
Elo=2550
Frequency of Mistakes in World Championship Matches

(Roring & Ericsson, 2006)
Consequences of available chess programs and availability of “tutors”

Reduction of the time taken to reach the level of grandmaster from around 10 years to 5-6 years

Emergence of world-class players in small countries, such as Norway (Magnus Carlsen)
In 1904 they discussed outlawing double summersaults because they were dangerous and impossible to master
Range of *modifiability* with extended *Deliberate Practice*

How many consecutive push-ups can someone perform without pause?

(H. H. Hart, 1974)
Charles Linster
Non-stop push-up records
6,006 Charles Linster (USA)
05-Oct-1965
...
10,507 Minoru Yoshida (JAP)
Oct-1980

Fu Bingli, a kung fu master from China
12 press ups with right finger
Flexible bodies

50 yards sprint in 18.7 s by Cadet Thomas P. Hunt

Guinness book of records distance record is **871 miles**.
Johann Hurlinger of Austria walked from Vienna to Paris in 55 days. For each day he walked on his hands for 10 hours at a speed of 1.58 miles per hour.
Part II. Traditional Learning of Professional Performance

The Goal of Professional Training

Independent Ability to Improve Customer Outcomes

Classroom Knowledge Acquisition

On-the-job supervised experience

Kirkpatrick’s four level model of evaluation
The most respected experts ("expensive" stockbrokers) are not markedly better in picking stocks on New York Stock Exchange than a random process, such as a monkey throwing darts.
Superior Performance

Chess
winning chess games
50 games (100-250 hours) for a rating

Teaching
superior ability to increase
students’ performance (post - pre)
500-1000 contact hours

Medicine
superior ability to increase
patients’ long-term outcome
200 – 400 contact hours
Minimal Effects of Traditional Indicators of Expertise

Long Education

Extended experience as a professional

Teaching

Image interpretation
Capturing Expert Performance
- Finding Representative Tasks for Essential Activities

Adriaan de Groot
(1914–2006)

Identify challenging and difficult situations, where experts are supposed to excel.
Capturing Expert Performance - Finding Representative Tasks for Essential Activities

Recreate the situation and task in laboratory

Actions and thoughts of novices and experts can be directly compared
<table>
<thead>
<tr>
<th>Domain</th>
<th>Presented Information</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chess</td>
<td><img src="image" alt="Chess Board" /></td>
<td><strong>Selection</strong>&lt;br&gt;Select the best chess move for this position</td>
</tr>
<tr>
<td>Typing</td>
<td><img src="image" alt="Typing Sheet" /></td>
<td><strong>Speed</strong>&lt;br&gt;Type as much of the presented text as possible within one minute</td>
</tr>
<tr>
<td>Music</td>
<td><img src="image" alt="Music Sheet" /></td>
<td><strong>Control</strong>&lt;br&gt;Play the same piece of music twice in same manner</td>
</tr>
</tbody>
</table>
Exceptional chess performance

Illustration of $r=0.8$

(van der Maas et al., 2005)
Response to Critical Unexpected Problems

From cover story in *Time Magazine* (March 10, 2008) on *The Science of Experience*
Part III. Mechanisms, Skills, and their Acquisition Through Deliberate Practice

Salchow
Increase in Complexity and Control as a Function of Years of Piano Training

<table>
<thead>
<tr>
<th>Years of piano training</th>
<th>Difficulty ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Virtuoso technique (double thirds, sixths)</td>
</tr>
<tr>
<td>9</td>
<td>Polyrhythms (3:4; 4:5; 6:7)</td>
</tr>
<tr>
<td>6</td>
<td>Octave scales (modern fingering)</td>
</tr>
<tr>
<td>3</td>
<td>Increased complexity of left hand</td>
</tr>
<tr>
<td></td>
<td>Expressive variation in loudness (dynamics)</td>
</tr>
</tbody>
</table>
Deliberate Practice

“individualized training activities especially designed by a coach or teacher to improve specific aspects of an individual's performance through repetition and successive refinement.

To receive maximal benefit from feedback, individuals have to monitor their training with full concentration, which is effortful and limits the duration of daily training”.

(Ericson & Lehmann, 1996, pp. 278-279)
Design and Sequencing of Training Activities

Professional teachers and coaches

* Monitor students’ development
* design training tasks for individual students
Accumulated Amount of Practice Alone During the Development of Amateurs and Expert Musicians
The problem with learning *during* work and play

Andy Murray (Scotland) in 2010
The problem with learning *during* work and play
A Sequence of Targeted Changes

Middle distance runners

Young & Salmela, 2010
Reaching Beyond One’s Current Ability
Part IV. Measuring Objective Performance

Perceptual Performance on Cardiac Auscultation

Reviews (Choudhry, Fletcher, & Soumerai, 2005; Ericsson, 2004; Ericsson, Whyte, & Ward, 2007)

Based on Butterworth & Reppert (1960)
Testing - Levels of Challenge

Perform a standardized task
such as a position in ballet
a kata in karate
running 100 m in less than 11.5s
Modifying the Course of Development

Increased myelinization

- Size of cortical projection areas
- Differentiation of muscle fibers

Perfect pitch
Flexibility of joints

Age
5 10 15
Developmental Interactions and Windows

Can anyone attain this type of shoulder flexibility?

Shoulder Joints of Expert Pitchers and Handball Players
The Amount of Deliberate Practice is Related to Maintenance

In Sports
(Starkes, Weir, & Young, 2003)

In Chess
(Charness et al., 1996)

In Surgery
(Waljee et al., 2006)

(From Krampe, 1994, and Krampe & Ericsson, 1996)

Practice hours in the last decade

Different Movements

![Graph showing relationship between practice hours and execution time in different movements.](Image)
Testing - Levels of Challenge

Perform a standardized task

Perform a complete routine in competition

Perform in an adversarial situation
Deliberate Practice with Simulators

Authentic test conditions with actors
(Kneebone et al., 2005)

Reinstating actual scenarios in anesthesiology
(Liu et al, 2009)
V. Optimizing Training Time

Training Surgical procedure

Essential Activ

Practicing Music Performance

Identify challenging and difficult parts,
Identify challenging and difficult parts,
The Importance of Acquired Mental Representations

Music  “Imagined music experience”

Golf  “Image of desired ball trajectory”

Desired performance goal

 Representation for how to execute the performance  Representation for monitoring one’s performance

Music  “Playing a piece of music”  “Listening to the played music as experienced by an audience”

Golf  “Execute desired shot”  “Comparison between desired and actual shot”
Immediacy of Informative Feedback

Sport training $\rightarrow$ performance
(1-2 years)

Investing $\rightarrow$ value
(10-20 years)

Medicine $\rightarrow$ patient outcomes
(12-36 months)
Mentor guided instruction in mammography

(Nodine et al., 1999)
1. Past medical tasks of diagnosis and medical treatments with subsequently collected information providing *a gold standard for accuracy*.

2. Past medical tasks that contain necessary information to allow a doctor to be able make *a diagnosis on the initially available information*

An archive with 234 radiographs and official case reports

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Accuracy of Diagnosis of Ankle Radiographs and Level of Training
Performance of 18 Trainees

Attending-level pediatric emergency medicine physician.

Preset criterion

Figure 3 in Pusic et al. (2011) How much practice is enough? Using learning curves to assess the deliberate practice of radiograph interpretation. Academic Medicine, 86.
Expert Performers are Better Able to Represent and Analyze Situations

(Kersting, et al., 2010, 2012)

(Ward & Williams, 2003)

(Tuffiash, Roring, & Ericsson, 2007)

Slowing Down (Moulton et al., 2010)
Exceptional abilities

Blindfold Chess

Alekhine beat most of the 30 skilled players while playing them simultaneously under blindfold conditions
Learning from an Incorrect Action of Anticipation

What aspect was overlooked
* When could this aspect have been discovered
* How to avoid similar mistakes in the future
* Develop new skills by deliberate practice
VI. Concluding Thoughts on Guiding the Development of Expert Performance

Going Beyond One's Current Ability

Guidance
Feedback
Anticipation of future demands

Teacher

Development

Limited perspective of student
Development of Performance
Recurrence of prostate cancer after surgical performance

(Vickers et al., 2007)
Prerequisites for Future Elite Performance
Hierarchical Building Blocks

Performance

Development

SOLID FUNDAMENTALS

REFINED REPRESENTATIONS

SPEED & ARTICULATION
Deliberate Practice

![Graph showing task difficulty vs. self-monitoring problem solving]

- Optimal
- Too easy
- Too difficult

Task difficulty

Self-monitoring
Problem solving

4-5 Hour Limit of full concentration
Percentage of Time that They Engaged in Deliberate Practice
When One Mistake Is Your Last Action
Mortal Combat between Fighter Pilots

(From Chatham, in press)
Actual dog fights with instructors flying enemy aircrafts
The Complex Process of Acquisition of Expert Performance