**SURGICAL EXPERTS – BORN OR MADE?**

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**INTRODUCTION**

Expertise in surgery needs to be cultivated in order to increase patient safety and improve practice. Expert practice consistently produces outcomes that are consistently superior to that of professional peers (Anon 2010; Ericsson et al. 2007). ‘Experienced non-experts’ (Mylopoulos and Regehr 2007) are individuals competent in performing familiar tasks, out-performing non-specialists, yet being unable to surpass their level of practice or adapt to new scenarios. These are known as ‘routine experts’ and must differentiated from ‘adaptive experts’ who seek new challenges and “explore and expand their current level of expertise” (Bransford JD et al. 2000; Mylopoulos & Regehr 2007). Medical expertise can manifested as improved patient outcomes, expressed in terms of mortality, morbidity, disease-free survival and quality of life. Cognitive capacity, long-term memory and problem-solving ability are intrinsic aspects of medical expertise, manifested through superior diagnostic capacity. Surgical expertise however requires superior performance in additional domains, such as responsible risk-taking behaviour, visual-spatial orientation and psychomotor ability, expressed as difficult decision-making capacity, economy of movement and automaticity (Schaverien 2010).

In order to determine whether expert surgeons are born or made, it is important to identify whether the characteristic features of surgical expertise arise through practice and training or whether they depend on intrinsic ability, specific personality types and circumstances in which individuals are born.

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**ARE SURGICAL EXPERTS ARE BORN?**

Sir Francis Galton¹ argued that individuals have a maximum physical and intellectual achievement ceiling, determined by heritable factors, which cannot be overcome through effort or experience (Ericsson, Prietula, & Cokely 2007; Ericsson et al. 2009). He concluded that in the same way physical features are inherited, so are intellectual and psychological characteristics predisposing to eminence or expertise: “men who are more or less illustrious have eminent kinsfolk” (Galton 1892). He gives credit to effort and environment in achieving expertise, yet he identifies hereditary ability as the rate limiting step in achieving expert status:

“I acknowledge freely the great power of education and social influences in developing active powers of the mind, just as I acknowledge the effort of use in developing the muscles of the blacksmith’s arm, and no further. The blacksmith... will find there are... feats beyond his power that are well within the strength of a man of herculean make, even though the latter may have had a sedentary lifestyle” (Galton 1892).

Firstly, Galton argues that even in the absence of social opportunity, naturally gifted individuals can adapt and compensate for unfavourable circumstances: “a good school offers little useful information, but teaches the art of learning. Another acquires the same art in the school of adversity” (Galton 1892). Galton uses family trees and ‘eminence tables’ to identify heritable achievement within families, using oarsmen, generals, scientists and musicians as

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¹ Sir Francis Galton (1822 - 1911): British polymath; statistician, founder of psychometrics and eugenics; author of “Hereditary Genius”
According to Galton’s theory, many surgeons are known to originate from surgically or medically prolific families. The Warren family of Boston produced four Professors of Anatomy and Surgery at Harvard Medical School between 1741 and 1928, two other physicians, as well as founding the Massachusetts General Hospital, demonstrating the first operation with ether anaesthesia, and introducing aseptic surgery and plastic surgery (Churchill 1958).

Secondly, Galton identifies innate psychological traits, such as perseverance and entrepreneurship, which individuals employ to achieve expert status. Two arguments are used to justify this theory. Firstly, individuals from underprivileged backgrounds are able to overcome hindrances, avoid mediocrity and emerge from obscurity to achieve professional expertise “in the subsequent race of life” (Galton 1892). Secondly, many individuals who benefit from optimal opportunities fail to achieve expertise on account of lack of intelligence or natural ability. To this extent Galton states that innate genius: “is not capacity without zeal, nor zeal without capacity, nor even a combination of both, but a nature which left to itself, will, urged by an inherent stimulus, climb the path that leads to eminence” (Galton 1892).

Surgical examples of natural cognitive and psychological predisposition towards achievement of expertise include:

1. John Hunter who transformed British surgery from a craft trade to a respected profession, in spite of the fact that he originated from “a poor but frugal and clever Scottish farming family” (Haeger 2000). He nevertheless showed an early interest in natural science and displayed an inquisitive nature which allowed him to dominate scientific society at that time through his work on operative anatomy, vascular, oncological and early transplant surgery (Moore 2005).

2. Sir John Bland Sutton displayed a similar early fascination with nature: “I liked school, but preferred to wander about the fields, orchards and lanes; I loved to catch butterflies... and learn to recognize birds by sight, flight and sound; to study their courting and nesting habits” (Bland-Sutton 1930)

3. The Paget family which exemplifies dynastic expertise in surgery in spite of relative social adversity: James Paget, the son of a Great Yarmouth brewer, rose from modest origins to become the founding father of surgical pathology, discovering Paget’s disease of bones, Paget’s disease of the nipple and Paget’s abscess (Venn 1922). His brother, Sir George Paget, became Regius Professor of Physic at Cambridge, whilst James’ son, Stephen Paget discovered the ‘seed and soil’ theory of metastasis on studying the natural history of breast cancer.

4. Harvey Cushing displayed ambition and determination to improve early in his life on the playing fields at Yale, the tennis courts of Baltimore and in the operating rooms at Johns Hopkins, focussing obsessively on excellence, performance and analysis of outcomes (Bliss 2005).

2A particular example is that of famous popes, who despite being the most successful of members of their families, and hence genetically superior in Galton’s view, had adoptive children who failed to achieve greatness despite the benefits of familial influence, education and access to resources.


4 Hunter was described as “plaguing folk with questions which no one could answer or even be troubled to know about” (Haeger 2000)

5 Sir John Bland Sutton (1855 – 1936): President of the Royal College of Surgeons of England, surgeon at the Middlesex Hospital in London, zoologist and Professor of Comparative Anatomy (Bland-Sutton 1930)

6 Sir James Paget (1814 – 1899): British surgeon and pathologist

7 Harvey Cushing (1869 – 1939): Professor of Surgery at John Hopkins and Harvard Medical Schools. First Chief surgeon at Peter Bent Brigham Hospital, Boston, Massachusetts. Father of endocrine surgery (Bliss 2005).
It can be seen therefore that the presence of familial patterns of expertise, natural intellectual ability and personality traits would justify Galton’s theories of inherited expertise.

Work by Lubinski supports this argument, showing that early achievement in precocious youth correlated with significant achievement later life, such as the acquisition of higher postgraduate degrees. This suggests that exceptionally able individuals are identifiable early in their lives, prior to acquiring environment skills favouring expert behaviour, thus supporting the thesis of the presence of ‘natural talent’ (Lubinski 2009).

CAN SURGICAL EXPERTISE BE ACQUIRED, DEVELOPED AND LEARNED?

Contemporary evidence, in contrast to Galton’s anecdotal or historic associations, suggests that expert level performance is acquired through discrete, albeit arduous steps in the presence of highly specific training conditions (Ericsson KA et al. 2006). Professional experience does not necessarily translate into expert performance (Choudhury and Fletcher 2005) and peer assessment of medical eminence has been shown to be a flawed method of identifying expertise (Ericsson 2007). This was demonstrated at Harvey Cushing’s expense, when a young but ambition assistant, Walter Dandy, performed Cushing’s signature operation on the pituitary in his absence with similarly illustrious results. Furthermore, Ericsson describes a poor association between a high IQ and expert performance (Ericsson, Prietula, & Cokely 2007), also seen in John Hunter’s delayed educational development. Therefore, the traditional definition of the surgical expert as the naturally gifted, experienced surgical polymath is inaccurate and attention must be focused on the mechanism, indeed the science, of developing expertise.

Deliberate Practice (DP) has been suggested as the method of acquiring expertise. This involves a focus on tasks beyond one’s level of competence (Ericsson, Prietula, & Cokely 2007), consciously identifying, pursuing and perfecting specific areas of practice whilst analysing and learning from errors. DP requires goal-directed learning, repetition and trainer feedback (Ericsson 2007) within a supportive educational environment. Central to the thesis of DP lays a focus on better quality of practice, rather than increased quantitative activity, in order to perpetually avoid the arrested development associated with routine expertise and automaticity of basic practice. The development of expertise through deliberate practice is gradual, sequential and time consuming, with an estimated 10,000 hours or 10 years separating the novice from attaining expert status (Ericsson, Prietula, & Cokely 2007). The mechanism of acquiring expertise through deliberate practice relies on surpassing a certain threshold of intellectual or physical intensity (Ericsson, Prietula, & Cokely 2007) which forces individuals to identify the most efficient method of performing a task, hence increasing the performance with which the task is fulfilled. Instruction, opportunity and familial support are seen as key factors in engaging in deliberate practice (Ericsson, Prietula, & Cokely 2007), as well as requiring an intrinsic motivation to actively challenge one’s performance.

Extensive evidence of DP can be identified in surgical experts:

1. Active pursuit of excellence: a. Cushing’s experimental animal laboratory where new procedures were pioneered; b. Alexis Carrel’s perfection of vascular anastomoses using techniques acquired from embroideresses.

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8 Walter Dandy (1886 - 1946): Neurosurgeon at Johns Hopkins Hospital (Bliss 2005).
9 “Cushing’s hardest and most delicate operation... imagine Cushing looking at me in resentment... it isn’t so exclusive after all as he said it would have us believe” (Bliss 2005).
10 Hunter was described as being “incapable of putting six lines together grammatically into English” (Moore 2005).
11 Ivan Galamian (1903 – 1981), Armenian violin teacher: “If we analyse the development of well known artists, we see that in almost every case, the success of their entire career was dependent on the quality of their practicing” (Ericsson, Prietula, & Cokely 2007)

3. Ability to relocate and travel in order to gain expertise: a. Bland Sutton’s travels to Billroth’s Allgemeine Krankenhaus (Bland-Sutton 1930); b. contemporary surgeons’ overseas fellowships and military campaigns.

4. Deliberate pursuit of lengthy training periods, manifested through current opposition towards working time limitations for surgeons (West et al. 2007).

It is important to determine nevertheless, whether certain individuals are born with a natural predisposition to engage in DP or whether this is an acquired skill. The familial link noted by Galton may be explained by opportunities of young experts to learn and engage in deliberate practice from an early age from parents that had successfully applied DP in their own careers. This may have indeed happened to the Warreins of Boston and the Pagets in London. According to the Ericsson’s principles of DP, both Cushing and Dandy benefitted from extensive moral and financial support from their parents, with whom they maintained a life-long correspondence and who instilled an early culture of industry, ambition and competitiveness in their sons.

Non-DP Evidence of Surgical Expertise

Studies have revealed incremental ‘milestones’ that mark the path from novice to expert performance, implying that expert status can indeed be reached if approached correctly.

1. Experts’ ability to deliver correct diagnoses features a decreased reliance on basic sciences (Schmidt et al. 1990), but a swift return to basic principles once challenged by an atypical problem (Norman et al. 1994). This highlights a subconscious progression towards automaticity based on a solid cognitive foundation. Experts can thus ‘encapsulate’ large volumes of knowledge which becomes integrated as ‘illness scripts’ used to accurately recall relevant information in the presence of specific triggers (Schmidt and Rikers 2007).

2. High performance is attained through creation of mental prototypes of specific concepts used as standards against which newly encountered problems are assessed (Rosch and Mervis 2010). Acquisition of expertise thus depends on the accuracy and number of prototypes mastered.

3. Accumulation of prior experience also allows individuals to engage in non-analytical reasoning, facilitating instant recognition and resolution of challenges (Wattenmaker et al. 1986).

This evidence suggests that experts are developed by acquisition of superior quality and quantity of knowledge and experience.

Volume-Outcome Relationships (VOR).

Surgeon and hospital case volume positively correlates with favourable patient outcome, as demonstrated in the performance of vascular surgeons in specialist centres (Holt 2009). The provision of mentorship in safe-learning environments, superior healthcare infrastructure and goal-directed surgical practice exhibited in such centres demonstrates the role of DP at an institutional level. VOR research demonstrates the role of the environment in the acquisition of expertise. Criticism of this argument includes experts’ biasness towards working in specialist centres, and patient selection or choice in receiving healthcare in high volume centres (Holt et al. 2010).

Surgical Simulation

The ability to gain technical competence in surgery has been further demonstrated by that fact that surgical simulators, whether bench-top, virtual-reality or immersive, can increase technical competency in novices (Black et al. 2010; Kneebone 2003; Kneebone et al. 2010; Kneebone and Aggarwal 2009; Kneebone 2006) and allow transfer of skills to clinical practice (Aggarwal et al. 2007). Simulators thus allow engagement in DP by providing opportunities for repetition, feedback and task-oriented learning, in a reliable and consistent manner.

Psycho-motor Skills Acquisition

Manual dexterity, demographics and school grades do not
necessarily correlate with surgical proficiency (Ericsson KA, Charness, Feltovich PJ, & Hoffman RR 2006), but visual-spatial ability is a better predictor of performance. Wanzel et al have demonstrated that this can be improved, even in initially under-performing novices, further adding to the argument that surgical expertise can be acquired from a technical perspective (Wanzel et al. 2002; Wanzel et al. 2003).

**Learning Environment**

The ability of different learning environments to impact on performance status implies that expertise is far too complex a concept to be solely determined by inborn features. Contextual interference describes the practice conditions in which learning occurs. To this extent, superior information processing activities has been shown to occur in difficult practice environments (Lee TD and Simon D 2004). Furthermore, regular training sessions (distributed practice) have been shown to be more effective than blocked or massed training in acquiring surgical skills (Moulton et al. 2006). This evidence suggests that the level of expertise achieved is in part depended on the type of practice and the learning environment in which the surgeon trains, partly divorcing expert status from the surgeon’s natural abilities.

**DISCUSSION**

Galton’s theory may be critiqued by the fact his conclusions are speculative, based on casual associations and lack the statistical basis to consolidate their validity. The outcomes of ‘Galton’s experts’ cannot be quantified or compared, and therefore their expert status cannot be confirmed. Furthermore, Galton lacked the necessary knowledge of genetics and modern concepts of heritability, such as meiosis, to explain the mechanisms of his findings. As such, his definition of ‘heritability’ is essentially observational and Mendelian in nature. Similarly, although the case of the Warren family is unanimously considered to be one of genuine expertise and academic rigour, other examples of familial ‘expertise’ in surgery may be attributed to nepotism, as described by Bliss: “Sons so often assumed a father’s profession, practice, and professorship that a dynastic tradition dominated Harvard medicine” (Bliss 2005). In addition, the ‘familial link’ of experts may be a manifestation of effective coaching habits and transferable skills that expert or successful parents instil in their children. An additional aspect of Galton’s work that needs scrutiny is the socio-political context in which he was writing. In the mid-19th century heritability and class eugenics were fashionable and convenient scientific principles. These were used to justify the power-hold of the governing classes in the face of social upheavals such as the 1832 Reform Act, the Corn Laws and revolutionary activity in Europe. Therefore, careful consideration needs to be given to the context in which his work was performed.

The principal counter-argument to Ericsson’s theory is its failure to take in account biological diversity. Meiosis lies at the centre of human reproductive biology with the purpose to generate genetic variety. This is further expanded by genetic mutations and phenotypical alterations which create a heterogeneous population able to evolve, survive and at times astound or horrify through its actions. It is logical that, as part of the extreme variety of human nature, certain individuals will have various abilities to perform in different tasks, including successful application of DP, even when adjustments have been made for training received and access to resources.

True multi-dimensional surgical expertise is a concept too complex to be explained either by genetic or phenotypical events in isolation. It is true that inherited intellectual or psychological characteristics can overcome environmental circumstances in order to achieve expert performance. It is also undeniable that some individuals have a greater ability to succeed at certain tasks compared to their peers, even when adjustments have been made for training, motivation, coaching and environmental support.

Conversely, expertise can be acquired through effective training, perseverance and directed effort (deliberate practice), which no amount of intellectual ability can replace.

Both Ericsson’s and Galton’s theories acknowledge the role of hereditary and acquired
features in achieving expert status, but differ in identifying the rate limiting step.

Current evidence therefore suggests that natural ability, environmental opportunity and personal effort are essential factors needed to achieve expertise. Once each has been achieved over and above a minimum threshold, a relative deficiency in one domain can be compensated by modifications in the other two. This may explain the wide variety of surgical experts and expertise observed.

CONCLUSION

The authors believe that surgical expertise can be taught and acquired through perseverance, ambition and industry, according to Ericsson’s principles of DP. However, the psychological drive, commitment and motivation needed to effectively engage DP to this end are probably innate or incidentally acquired through independent environmental factors. A minimal level of cognitive capacity based on biological inheritance or diversity is also needed as a platform on which expertise can be built.

Surgical expertise is therefore an acquired characteristics, but surgical experts are born with a superior ability to acquire expert status.

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