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Searching the real world for signs of rising population intelligence

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Abstract

Average raw scores on IQ tests have been rising for decades but it still is controversial whether population intelligence really is increasing. The present study looked at several real world indicators for evidence of a rise. First, the prevalence of mild mental retardation in the US population and elsewhere has been steadily declining for decades. Second, players in various intellectual games, particularly chess but to a lesser extent bridge and go, are reaching high performance levels at earlier and earlier ages. There are many more prodigies. Third, scientific productivity, measured by number of journal articles and patents awarded, has risen greatly over the last few decades, even though much top intellectual talent may be shifting from science. Finally, I surveyed perceptions of teachers who had taught in high schools for over 20 years. Most reported perceiving that average general intelligence, ability to do school work, and literacy skills of school children had not risen since 1979 but most believed that childrens's practical ability had increased. Most reported perceiving a decline in students's motivation, which may be affecting their perceptions of general intelligence. All these trends have various possible causes other than rising intelligence. However, together, and with other recent empirical evidence, most indicators suggest population intelligence really could be rising.

Keywords: Flynn effect; Rising intelligence; Giftedness and retardation; Chess; Go; Bridge; Scientific productivity; Teacher perceptions

1. Introduction

Average raw scores on IQ tests have been rising for years (Flynn, 1984, 1987, 1999), by an estimated three IQ points per decade (Neisser, 1998). This rise, dubbed the Flynn effect, has received much attention, though its exact nature recently was questioned (Rodgers, 1998). The

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rise has been attributed to such factors as more environmental stimulation, better diet and health, more education, and increased visuospatial ability due to living in a more visual world (Neisser, 1998; Jensen, 1998).

However, it still is controversial whether humans actually are getting more intelligent, whether average Spearman's *g* level is rising. Some researchers say that it is (Schooler, 1998; Lynn, 1998; Colom, Andrespueyo & Juanespinosa, 1998), noting that IQ score is a sound measure of *g* (Howard, 1993) which correlates with grades and job performance (Gottfredson, 1997; Gordon, 1997) and physiological measures (Howard, 1995). They point to analogous rises in other population parameters since 1945, such as myopia, perhaps due to increased close work of children, and height. They note the brain's great amenability to environmental influences during development and the general improvement in Western nations in factors known to raise IQ, such as diet, stimulation and education.

Other researchers are skeptical. Flynn himself suggests that only some ability specific to IQ tests is rising; "abstract problem-solving ability" (Flynn, 1987), or that gains may only be in such specific abilities as mathematical prowess. He points out that projecting the IQ gains back in time would suggest that the average person in past centuries would be considered mentally retarded today. Jensen (1998) suggests care in comparing IQ scores across generations.

This important issue has been much debated (Neisser, 1998; Jensen, 1998), but in something of a data vacuum. Researchers mainly have noted broad environmental trends, have queried Flynn's notion of intelligence, and have cited studies using tests (Lynn, 1996). For instance, Lynn and Cooper (1994) looked at changes in the pattern of inter-correlations between WISC sub-scales. At lower IQ levels, sub-scale scores correlate more highly. They reasoned that, if population intelligence actually is rising, inter-correlations should decrease over time, which they found in Japanese data from 1951 and 1975 (Jensen, 1998, p. 321–2, notes a problem in interpretation, that sub-test score variance may have changed). Flieller (1999) found children scoring higher on standard Piagetian tests in recent years than in earlier decades, consistent with rising *g*.

However, non-test data are needed, which might settle the issue in two major ways. The best way is with a direct physiological measure of *g*, which, although *g* has physiological correlates, no one has yet developed (while Lynn, 1990, 1998 argues that brain size correlates with IQ and improved nutrition has raised average brain size, this measure remains controversial).

The second way is indirect; to find clear evidence of an increase in the "real world", where rising *g* should be impacting. Flynn (1987, 1999) argues that the apparent lack of such impact means that population intelligence is not rising. He says that there is no explosion of scientific and artistic output, or any more gifted children, and teachers are not saying that students are becoming brilliant. He points to counter-evidence, such as declining numbers of patents awarded (evidently in France and Holland) and decreasing SAT scores.

Parenthetically, this question is interesting even if a physical measure study showed that *g* really is rising. We still would like to know the impact.

However, finding relevant real world evidence actually is very difficult. What real world changes would occur and how could they be unequivocally ascribed to rising *g*? There are various difficulties. First, performance in intellectual domains is determined only partly by *g* (Jensen, 1998). The relationship between native talent and achievement is very complex. Many other factors impact, such as motivation, amount of domain-specific knowledge needed to excel, social background factors, presence of a mentor, creativity, and opportunities to train and perform

(Simonton, 1999). These may be rising or falling themselves, masking any effects of rising *g*. It even is problematical how rising *g* might map into various real world performances. It might impact in various ways, even setting up cascading feedback loops, or might need time to reach a critical mass.

Second, there is no obvious way to tackle the problem experimentally, only with correlational studies, with their problem of assigning causation. This problem is well-known in fields mostly limited to correlational studies, where researchers may endlessly debate why inflation, unemployment, and crime rates rose or fell over a particular period. They look for natural experiments, which are rare, and at other possible causal variables, but causation never is certain. Because so many factors change over time (e.g. historical experiences, child-rearing practices, opportunities, and the difficulty of fields such as physics as knowledge increases, for example), it is difficult to say that rising intelligence (or anything else) might be even partly responsible for apparent performance increases. Third, real world longitudinal data may be incomplete, or not very useful because they were collected for different purposes, or subject to biases and other limitations, and be hard to obtain. Fourth, *g* could be rising but not measurably manifesting in the real world.

Nevertheless, some evidence does bear on the question. Some is anecdotal and logical. There are reports that military recruits learned new skills faster in World War II than World War I (Jensen, 1998). Technological society is becoming ever more complex, but the young cope. Lynn (1990) notes that many more students now study at university in Western nations, though some writers complain of worsening academic standards and curriculum simplification (Crowley, 1997). Many American universities must run remedial reading and writing courses (Hunt, 1995). Others complain about the "dumbing down" of the school curriculum (Williams, 1998) and of television shows and films.

There are a few formal studies. As mentioned, Flynn (1987) cited declining patent numbers and SAT scores and no evidence of more gifted children (determined by scanning newspapers). However, Howard (1999) found that US patent numbers actually rose significantly from 1963. Also, he argued that the SAT score decline may be due to many factors, such as a less selected sample taking the test and because widespread poor motivation and declining workload expectations in US schools are worsening academic skills (Steinberg, 1996; Jensen, 1998).

Howard (1999) looked at chess performance since the inaugural FIDE (international chess federation) rating list in 1970. The list is based on an objective measure of each player's chess performance, on a scale from about 2000 to 2800. The rating changes with each game played, depending on result and opponent's strength, and thus reflects current prowess. Chess is a good candidate for detecting an impact of rising *g* because the task has remained the same for decades, most chess tournaments are open to all, chess skill correlates with IQ and visuospatial ability (Horgan & Morgan, 1990; Frydman & Lynn, 1992), and the task requires many elements of intelligence, such as use of working memory, complex reasoning, and use of much domain-specific knowledge that players spend many years acquiring (Holding, 1985). Since 1970, players were reaching high performance levels at progressively earlier ages. For example, the median age of the top ten dropped from the late 30s in the 1970s to the mid-20s in the 1990s. Evidence discussed in detail suggested that the trend was due to rising intelligence. For instance, though physical sports records are continually improving, this usually is ascribed to factors such as drug use, sports psychology and better equipment and to earlier adolescence allowing players to reach needed physical milestones sooner. Another account is that more talent is being mobilised for chess. However, in the Soviet Union where chess was the national sport, this had been occurring since the 1920s (Charness & Gerchak, 1996). If *g* was not rising, the age trend should have started much earlier.

Finally, Rosenau and Fagen (1997) measured changing "integrative complexity" (a measure of sophistication) of texts (congressional speeches, newspaper editorials, etc) produced by elite individuals between 1916–1932 and 1970–1993. Text complexity indeed rose over this period, but possibly due to increased education or other factors.

Therefore, more real-world data really are needed to inform the debate. Given the methodological problems listed above, inherent in the research question, the best research strategy is to examine many different indicators. Change or constancy in any one may have many interpretations but a preponderance consistent with rising intelligence may be more convincing. The present study looked at four indicators.

2. Prevalence of the gifted and mentally retarded

An intelligence curve shifting upwards should mean progressively fewer children with mild mental retardation and more gifted children. Obviously, the Flynn effect itself could suggest this result without rising *g*, but publishers now re-norm tests periodically.

What data exist on changing prevalence at the extremes? Flynn (1987) argues that there is no evidence of more gifted children, citing his search of media reports. But, it is not clear how newsworthy such children would be. Howard (1999) contacted various gifted child research centres, but none knew of any longitudinal statistics being collected. Additional problems are that criteria for giftedness vary widely, schools differ greatly in ability and willingness to identify them, and many go unidentified (Howard, 1991). There is some evidence of more US high school students gaining advanced university placement (Reisberg, 1998), but possibly due only to changing attitudes toward such acceleration. There is a long-term study of mathematically US precocious youth identified by high SAT scores at an early age (Benbow, Lubinski & Suchy, 1996) but it is hard from reports to see if the prevalence of such children has risen. However, the US National Centre for Education Statistics website does list some data on gifted children, giving numbers in various states, but only since 1989. No data are given for many states, which evidently do not run programs or collect statistics. The data show wide variance in prevalence between states. In 1993–4, 14% of all school children in Michigan were identified as gifted and talented (up from 11.6 % in 1989–90) but only 2.4% in Alabama (marginally down from 2.5% in 1989–90) and 1.3% in Idaho were. These differences may reflect different attitudes toward the gifted. So, overall, little data on gifted children can be brought to bear.

Mental retardation is a social rather than a natural category (Singh, Oswald & Ellis, 1998). It refers to individuals with generally subnormal intellectual functioning, usually having an IQ score below 75 (or 70) and deficits in adaptive behavior. There is a distinction between mild (IQ 75 or 70 down to 50) and severe (usually less than IQ 50) retardation. Most cases are mild, often considered largely to be due to early environmental deprivation, and in particular low levels of stimulation and poor diet, two factors implicated as possible contributors to the Flynn effect (McDermott & Altekruse, 1994). Indeed, the prevalence of mild retardation correlates with poverty, and more environmental stimulation may decrease its prevalence (McDermott & Altekruse, 1994). Severe cases may be due to many factors, such as alcohol consumed during pregnancy, genetic syndromes, and injury (Beirne-Smith, Patton & Ittenbach, 1994). Many mild mentally retarded are identified in their first years of school, when they cannot cope with the curriculum, and get referred for testing and perhaps special schooling (Beirne-Smith et al., 1994, p. 234). Many do not look retarded and may function well enough outside school, leading to the term "six hour retardation" (Beirne-Smith et al., p. 122).

There are some data on prevalence of both types. Lynn (1990) cites a Swedish study which found lower prevalence of retardation in an adolescent population; "0.38% instead of the expected 2.1%". The extensive review of Roeleveld, Zielhuis and Gabreels (1997) concluded that the prevalence of *severe* retardation in various locales over the last few decades has stayed at a roughly constant "true prevalence" of 0.31%. A study of Down's syndrome cases in an area of England found little change in prevalence from the 1950s to the 1990s (Bound, Francis & Harvey, 1995), although Bermejo, Martinez and Luisa (1998) found a decline in Down's syndrome cases in Spain from 1976, which they attributed to prenatal screening (devised in 1969) and abortion.

Some data suggest that the prevalence of *mild* retardation indeed is declining. Skarbrevik's review of many studies concluded that its prevalence declined in Scandinavian nations from 1961 to 1989, and he attributed this to increasing population intelligence (Skarbrevik, 1990). However, determining the "true prevalence" of mild retardation is very difficult because norms and labelling practices differ across time and nation (Roeleveld et al., 1997). Flynn (1985) notes some problems with norms.

We may get a better idea of prevalence changes by using ability to cope with the school curriculum as an external criterion. As mentioned, many mild retarded are identified in school, when they cannot cope with the curriculum. We could examine prevalence of children placed in the mild category by reference to the school system, children for whom the normal school curriculum is too difficult. The US Office of Special Education gives annual data on children in special education programs on the US National Centre for Education Statistics website from the 1976–7 year. Are there fewer retarded children?

Fig. 1 shows US school children with a disability in special education programs as a percentage of total kindergarten to grade 12 enrolments from the 1976–7 to 1996–7 school years. The proportion of all disabled rose from about 8% to about 12% and the proportion identified as

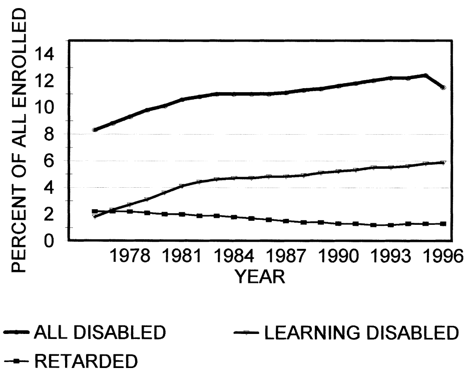

Fig. 1. Proportion of all kindergarten to year 12 students in special education programs, diagnosed as learning disabled, and diagnosed as mentally retarded in US schools. Source: US National Centre for Education Statistics.

learning disabled rose to about half of the total. However, the proportion of mentally retarded progressively dropped, from 2.2% in 1976–7 to 1.3% in 1997–8. The decrease is reflected in recent age statistics. In the 1996–7 school year, 24.4% of children aged 18–21 in special education programs were labelled mentally retarded, versus only 12.6% of those aged 12–17 and only 9% of those aged 6–11.

This drop may have explanations other than rising *g*. First, the label "learning disabled" is more palatable and may be pinned on children who previously would have been labelled retarded (Polloway & Smith, 1983; Polloway, 1985; MacMillan, Gresham, Bocian & Lambros, 1998). The two are defined differently. Criteria for diagnosis of learning disability vary but usually involve at least near average IQ score and very poor achievement in at least one area, such as reading (Culatta & Tompkins, 1999, ch. 4). However, criteria may not be consistently applied (Gresham, Siperstein & Bocian, 1996). Second, outdated or poor norms may be used.

On the other hand, children only would be referred for testing when not coping with school work, and perhaps fewer really were being referred. However, I could not obtain data on percentage being referred.

3. Performance in intellectual games

Another possible indicator of rising intelligence is improved performance in intellectual games. Performance on all mental tasks correlates with *g* and playing intellectual games should be highly *g*-loaded. As mentioned, studies do show correlations between IQ and chess skill, though I could not find any studies for other games. Other advantages are that the task of playing stays essentially the same over decades, often people of all ages take part and so different generations can be directly compared, there are objective performance measures, and most games have few barriers to entry. If population intelligence is rising, this domain would seem the best chance of detecting it.

Howard (1999) found that chess players were reaching high performance levels at earlier ages. However, the study had several limitations, mainly using post-1970 data, the year that the international rating list began, and looking only at chess. The age decline could have been from a high base in 1970 or have been due to some non-*g*, chess-specific factor, such as better instruction or more people playing.

So, here I looked at two obvious questions. First, was the downwards age trend in chess coming off a very high base in 1970? Perhaps the 1970s had unusually skilled older players, and much younger top players predominated in earlier years. This is unlikely, since it has been thought for most of this century that a player's performance peak is at age mid to late 30s (confirmed in a rating study by Charness, Krampe & Mayr, 1996). I obtained some data from 1950 onwards, which give some indication. Second, is the same age trend occurring in other intellectual games such as bridge, go, Othello, draughts (checkers), scrabble, backgammon, poker, and computer games such as Tetris? If so, this would suggest that rising intelligence is inducing the chess age drop.

However, gathering useful data on other games proved very difficult. Chess is the best test case because many chess organisations exist, there are objective performance measures and birth dates are readily available. For other games, international organisations do not exist, or most existing ones would or could not provide data, top players and birth dates could not be determined, participants were too few, or relevant data just had not been collected anywhere (e.g. the US Go Federation has less than 2000 players and only recently began to record birth dates). Most computer games are too new for useful comparisons. I could get some useful (and still limited) longitudinal data only for bridge and go.

3.1. Chess

The rise in text sophistication noted by Rosenau and Fagen has a chess parallel. The standard of play today is seen as higher than ever, and the current de facto world champion (Kasparov) is seen as the greatest player ever. An informal study by Nunn (1999) supports the view. Using the computer program Fritz's "blundercheck" mode, which scans games for serious errors, he compared the standard of play in two major tournaments across the century; Carlsbad, 1911 and the Biel Interzonal, 1993. Both had many of their era's best players. Performance was much better in 1993, players making many fewer serious errors. Nunn concluded that the 1911 tournament would be considered very weak today.

Howard (1999) noted that, since 1970, chess has had an increasing number of prodigies (chess gifted children), despite fewer youngsters in the aging Western population. Some pre-1970 data relating to the Chess Olympiad and the prestigious international grandmaster title were obtained. The title itself dates back to 1914 but only in 1950 did FIDE officially award it. Table 1 shows the age records for gaining the grandmaster title from 1950, either a player's exact age when receiving the title (if known) or age on July 1 of the year receiving it. The table shows the record being broken several times in the 1950s, but the 1957 record stood until 1991, and thereafter was repeatedly broken. The record setters in the 1950s were exceptionally talented, all except Bronstein becoming world champion.

The same age record decrease has occurred with another prestigious performance-based title, the US Chess Federation (USCF) master title. The age record has been broken several times recently, extremely young players gaining the title. In the last few years, some record-holders have been; Jordy Reynaud aged 10 years, 7 months; Vinay Bhat 10 years, 6 months, and in 1998 Hikaru Nakamura at 10 years, 2 months, only about 29 months after learning to play. However, efforts to gain longitudinal data on this title from the USCF were unsuccessful. Parenthetically, in 1998, Irina Krush set another age record by winning the US Women's Championship aged only 14 years.

I examined whether the median age at which players were winning the grandmaster title has been steadily dropping since 1950. FIDE did not respond to requests for data but data were available from chess encyclopedias, Gaige (1987), and FIDE's website. Each player's age on July 1 of the year the title was obtained was calculated, or the exact age was used if known. Because samples in some years were small, data were combined for each decade. Values for all decades except the 1990s are reliable but the 1990s value is an approximation. Repeated requests to FIDE for post-1990 data were unsuccessful. However, I obtained from other sources a list of title winners in 1990, 1998, and 1999, and their age on July 1 of each year was determined. I also could determine title winners from 1991 to 1997, but for most not the exact year. To get an approximate value for the 1990s, I therefore assumed that players for whom the year was not known received the title in the interval's midpoint year, 1994, computing their age on July 1, 1994 accordingly.

The resulting value probably is quite close to the true value. For about 7.4% of 1990s title winners (but none in other decades), no birth date could be determined and they were excluded.

Fig. 2 shows that grandmasters have been getting younger; there are many more prodigies. The figure suggests a drop from the 1950s, leveling off to 26 years old in the 1980s and 1990s. (While the 1990s figure is an estimate, the median for title winners in 1990, 1998 and 1999 combined is close at 25 years old.) The 1950s value has an interpretation problem. Only in 1957 did FIDE use objective performance-based data, the title being awarded by vote of FIDE beforehand. The sample for 1957, 1958 and 1959 is small, but had a median age of 29. If we use that value instead, the age trend downward really began in the 1970s. The proportion of teenagers gaining the title rose steadily. In the 1950s, only 3.3% of new grandmasters were teenagers, in the 1960s none were, in the 1970s 2.8%, in the 1980s 7.8%, and in the 1990s 15.0%. (Note the problems with the 1990s figure. However, the value for 1990, 1998 and 1999 combined is close at 12.5%.)

The Chess Olympiad is held every 2 years. It features a six player team from each nation, usually the best each can field. Howard (1999) found a drop in median age of the Soviet team (or Russian from 1992) from 1970. Fig. 3 presents the median age of the six players in each Olympiad's winning team (out of all nations) from 1950 to 1998. From 1950 to 1970, the median age

Table 1
Some chess and bridge age records by year

Year	Player	Age
International Chess Grandmaster		
1950	Bronstein	26 years
1952	Petrosian	23 years
1955	Spassky	18 years
1957	Fischer	15 years, 6 months
1991	Polgar	15 years, 5 months
1994	Leko	14 years, 5 months
1997 (March)	Bacrot	14 years, 1 month
1997 (October)	Ponomariov	14 years, 17 days
1999	Bu Xiangzhi	13 years, 10 months
American Contract Bridge League Life Master		
1939	Crawford	23 years
1952	Freeman	18 years, 10 months
1961	Barton-Paine	18 years, 12 days
1965	Larsen	15 years, 11 months
1968	Livesey	15 years, 5 months
1973	Levin	15 years, 4 months
1975	Freed	15 years, 20 days
1976	Barnes	14 years, 11 months
1977	Cochran	14 years, 5 months
1980	B. Hsieh	13 years, 7 months
1981 (June)	Kaufman	13 years, 4 months
1981 (September)	D. Hsieh	11 years, 10 months
1988	S. Hirschman	11 years, 9 months
1990	Wooldridge	11 years, 4 months
1994	D. Hirschman	10 years, 2 months

mainly fluctuated around the average peak age of players of 35. The sharp trend downwards begins after 1970 and is not coming off a particularly high base.

3.2. Bridge

Bridge is one of the world's most popular intellectual games, being perhaps more popular than chess. Bridge is well-organised, with many bridge federations, rating systems and master titles. The latter are awarded differently from chess. Gaining a life master title is based on an accumulation of "master points" won in tournaments and the world rating system depends on a lifetime accumulation of master points. But point counts may not represent current strength, because master points cannot be lost as chess rating points can.

Bridge play differs from chess in various ways. There is a partner, players have incomplete information, and success depends partly on psychological knowledge and the luck of the cards dealt (Charness, 1989). The game has two parts, bidding and playing the cards, and the skills of each may be independent. Much less is known about psychological processes during play in bridge than in chess, but there are parallels. For example, players search an immense problem

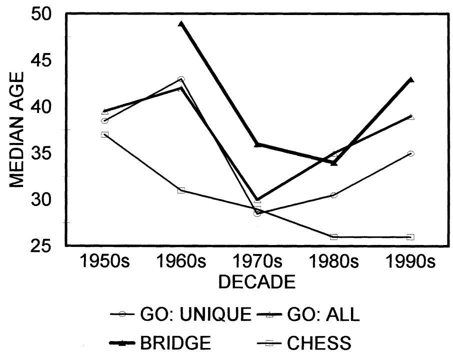

Fig. 2. Longitudinal trends in median ages of gaining the chess grandmaster title, various go titles, and the contract bridge world championship title.

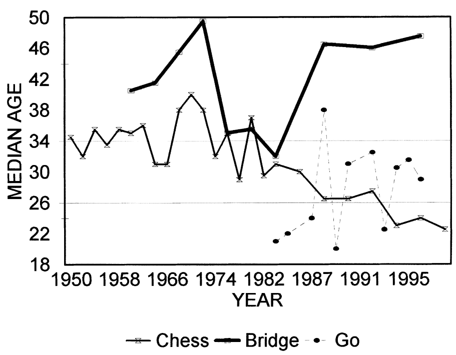

Fig. 3. Longitudinal trends in median ages of teams in chess and bridge olympiads and the China versus Japan go matches.

space and need guiding heuristics. Charness (1989) cites a few studies of bridge skill which show parallels with chess expertise findings. Experts see clusters of cards as chunks and higher skill levels are linked with faster and more accurate bidding. Experts have a large knowledge base and skill differences are linked to more and better tuned productions. We would expect skill level to correlate with IQ, but as mentioned, there are no data on this. Is there any evidence of a similar age trend in bridge as in chess?

It was difficult to get relevant data. However, Francis, Francis and Truscott (1994) provide data on players and tournament results. Some additional data were obtained from bridge federations.

Table 1 presents age records for the US Contract Bridge League life master title. There seem to be many more bridge prodigies with time, the age record steadily dropping in bridge as in chess. The present record holder reportedly only began playing bridge the year before. It is interesting to note that the USCF chess master and US bridge master age records have decreased to about the same age.

Fig. 2 presents median age of the players in the World Open Championship titles (consisting of two player teams). All ages are as at the age on January 1 of the year considered, as most birth dates available listed only year. The event was held every 2 years. Because of the small samples, data are median age of all players on the winning teams for each decade. The trend partly parallels the trend for chess grandmasters, going downwards from the 1960s, but then it rises in the 1990s.

Fig. 3 gives median age of the six players in each winning team in the Bridge Olympiad, held every 4 years since 1960. The median age increased from 1960 to 1972, then declined and then rose from 1982. Clearly, top Bridge Olympiad players are not getting progressively younger, with players being displaced by younger, stronger players. The trend upwards from 1964 occurred because the exact same French team won three times in a row.

3.3. Go

Go seems more similar to chess than does bridge and therefore seems a better game to look for age trends. There is no element of luck, competitors play individually, and have complete information. There is little research on psychological processes during play, but like chess, one would expect skill to correlate with IQ and for visuospatial ability to be important as players must calculate long sequences of moves. One also would expect experts to chunk piece patterns and to have a vast amount of domain-specific knowledge (although Reitman, 1976, examining one go expert, suggests a difference from chess).

Go is very popular and well-organised in Japan and China, but less so elsewhere. There is no real international organisation or world championship, or numerical rating system where a rating changes with each game. Go has professional players and tournaments and a ranking system, ranging from first to ninth dan. However, go has a major problematical aspect for the present study. Unlike chess and bridge, there are great barriers to entry at upper levels. Players generally must start training in elementary school and must serve a lengthy apprenticeship with a top player. They only are admitted to the ranks of professionals and to dan levels by vote of other professionals (Bozulich, 1992). This system favours the pre-eminence of older established players who could keep out young, talented players. The time required and difficulty of rising may discourage great talent.

It was difficult to find data for useful longitudinal comparisons. I could not get enough useful data on the ages at which players made the ranks of professionals or various dan levels. However, Bozulich (1992) and various go federations provided some data. The most useful thing to look at was the winners of the seven major Japanese go titles, which periodically are decided by major competitions. These are the prestigious Kisei, Tengen, Meijin, Honinbo, Judan, Gosei, and Oza titles. Most were first awarded in the 1950s. The competitions for each title usually are held every year and the winner is determined by a series of matches. Is the age of title winners dropping?

Fig. 2 gives the median age of all title winners combined ("go: all") and of first-time winners ("go: unique") of each title in each decade. The age trend partly parallels that for chess and bridge, decreasing from the 1960s to the 1970s but then rising somewhat. However, the unique go title winners in the later decades are much younger than those in the 1950s and 1960s.

There is no real go olympiad. Perhaps the closest equivalent is the annual (usually) team match between the two strongest nations, Japan and China, which ran until 1996. The span of years is fairly short. Fig. 3 presents median age of the winning team over this period. The data are quite variable, usually because the Chinese team started much younger and got older and the Japanese team got younger. The data show no clear downwards age trend.

3.4. Discussion

The data show some variability but some conclusions follow. The chess age drop was not coming off a very high base in 1970. Players really are performing well at younger ages now. The trend downwards really seems to have started around 1970; at least there are signs of a big impact at the top levels around then. If it is due to rising intelligence, a critical mass may have been reached about then. Overall, there is some evidence for an age drop in bridge and go parallel to that of chess but these are much less pronounced and evidently halted earlier. However, the lack of more pronounced age trends may be due to a number of extraneous factors, particularly in how the games are organised. Performance may correlate much less with IQ, bridge in particular may be less popular with the young and may require much more use of psychology in the bidding, which favours the older. It depends partly on a partner. The peak age for bridge may be much older. In go, a critical factor may be the barriers to entry. Finally of course, it may be that the age trend in chess is due to factors specific to chess and has nothing to do with rising intelligence, but the evidence here for some age drop in bridge and go suggests that this is unlikely.

More work on intellectual games will help. However, it is difficult to see how this could be done, given the difficulty of obtaining data. Time may be revealing, though. Given that the peak age for chess is the late 30 s, when average IQ stops rising, the average age of top chess players may rise back up.

4. Scientific productivity

Flynn (1987) argues that a rise in intelligence would produce a boom in scientific productivity, which he says is not occurring. He states (p. 187), "[Various newspapers] ... contained not a single reference to a dramatic increase in genius or mathematical and scientific discovery during the present generation ...". However, the argument has problems. IQ score is a major factor in science performance up to a threshold of about 120, beyond which motivation, creativity, opportunities and other factors become important (Howard, 1991). "Scientific genius" is partly a function of personality, opportunity, and being born at the right time (Simonton, 1988). Though the pool of people able to do research would expand, only some would have other needed characteristics. Various factors varying over the decades may affect scientific productivity, masking any effects of rising *g*. First, funding for basic research may vary greatly, and particular fields may fall in or out of favour. Second, fields change over time, making comparisons between decades problematical. It may take much longer to reach the frontiers of knowledge in later decades, for example. In the early stages, there may be relatively few researchers and different problems to solve (Gupta & Karisiddappa, 1996). A field's easy problems may be solved and the remaining ones be intractable. Some fields even become relatively worked out, with their major problems solved, and so productivity declines. Horgan (1996) even argues that science itself soon will be worked out. The increasing cost of equipment has meant more team work in some fields. A particle physics paper may have hundreds of authors.

Various factors have changed over the decades which might raise scientific productivity even without rising *g*. In some ways, science is easier to do. Computerisation enables simulation of models, sophisticated data storage and analysis, running of experiments, and easier access to bibliographic information. Also, there are many more scientists. While some argue that much of the useful output is produced by a small group of scientists (Gupta & Karisiddappa, 1996), others present evidence that the proportion of a population with the ability to contribute to scientific advance is much larger than the proportion who actually become scientists (Cole & Phelan, 1999).

But, other factors might decrease productivity. Stephan and Levin (1992) argue that the scientific capacity of the United States has declined over the last few decades, partly because the scientific community is aging and because they say that the average quality of new scientists is declining. Science has become a less attractive career. The United States produces about a third of the world's science but evidence suggests that intellectual talent has been shifting to more attractive fields. For example, Bowen and Schuster (1986) say that, between 1945 and 1969, 1.2 times as many Phi Beta Kappa (an elite student society) members chose careers in business, law and medicine as in academe. But in the 1970s, five times as many did. US science graduate students now often are foreigners as locals shift to better paid fields (North, 1995). In Australia, the entrance exam mark cutoffs to enter university science courses have steadily dropped over the years as fewer students apply, while top marks are needed for courses in finance, law and medicine.

Nevertheless, we can look at some data. Anecdotally, science has advanced rapidly over the last few decades, especially in neuroscience, molecular biology, and astronomy. The pace of technological advance seems to be ever more rapid. However, this largely may be due to development of new methods, such as the Hubble Space Telescope, space probes and brain imaging. Anecdotally, individual scientists are more productive. Anecdotal reports from university recruitment committees say that new graduates applying for jobs have published more and start publishing earlier, "... today's hires often begin their new jobs with more publications to their credit than many of their senior colleagues" (Cassuto, 1998).

Common measures of scientific productivity are numbers of patents awarded and articles published in refereed scientific journals. As mentioned, Howard (1999) reported that US patents awarded had risen greatly (from 48,871 in 1963 to 121,697 in 1996), faster than world population had grown. A subfield of sociology, publishing in such journals as *Scientometrics*, examines scientific productivity and variables affecting it, often using a number of articles as a measure. However, this measure has various well-known flaws, making comparisons across generations difficult. Indeed, a field may be producing many journal articles but actually progressing very slowly. Anecdotally, pressures to publish have grown, as academic managers demand ever higher counts and researchers try to maximise numbers by such practices as breaking work into many parts (the least publishable units). Opportunities to publish may grow as journals expand and new ones arise. It also is difficult to use counts to compare across fields because publication practices vary widely. In astronomy, for example, it is difficult to tell if a journal actually is refereed (Davoust & Schmadel, 1991). Opportunities to publish vary, one estimate being that a slot is available of about one half an article a year for each psychologist and three for each biochemist (Odlyzko, 1995). Average publication rates differ greatly across fields. As well, a few prolific researchers may contribute much of a field's literature (Davoust & Schmadel, 1991).

However, I examined some Institute of Scientific Information (ISI) data from 1955 to 1997, from the ISI's *Science Citation Index Guide* in 1997, which includes lists of source publications. Fig. 4 presents numbers of articles published in each year and number of unique source authors. The latter category naturally would not include all scientists, as many PhD graduates never publish an article (Cole & Phelan, 1999). Data on author numbers from 1966 to 1979 could not be obtained, despite repeated requests to ISI. Also, ISI's published figure for authors in 1965, nearly double that of 1964, may be a misprint.

Fig. 4 shows a huge rise in number of articles published. So, by this measure scientific productivity has risen greatly. However, the number of unique authors has also risen, while the actual productivity per unique author has declined slightly, from 0.967 in 1955 to 0.771 in 1997. This may have many causes, such as the trend to multi-author papers, rising cost of equipment, shorter career spans, and so on.

The data suggest that scientific productivity has risen. Indeed, in many fields of science and in mathematics, the annual number of articles published is doubling every 10–15 years (Odlyzko, 1995). The numbers in Fig. 4 even may underestimate the growth in productivity. Competition for publication space often is severe. Many journals have high rejection rates, taking only the best of those submitted. The number of articles never published may have risen greatly, too.

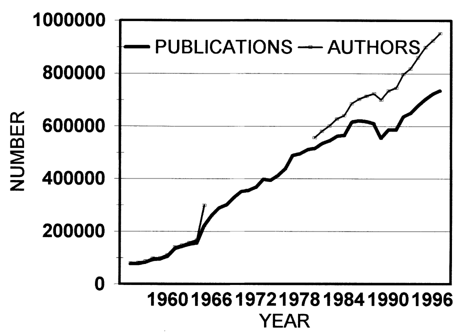

Fig. 4. Total number of source articles published in science and unique source authors each year since 1955. Data for authors between 1965 and 1979 were unavailable. Source: Institute for Scientific Information.

As with other indicators, the rise may have nothing to do with increasing *g*. Nevertheless, the increase is what might be expected from rising *g*, and Flynn's argument that scientific productivity has not risen does not hold up.

5. Teacher survey

If *g* is rising, school children should be learning faster and more, given the relation between learning and IQ (Howard, 1995). Teachers might notice and report this, and their evident failure to do so suggests that *g* is not rising (Flynn, 1987; Jensen, 1998).

However, there could be many reasons why not. First, an average teaching career span may be too short to note changes. Second, memories of students's abilities in previous decades may fade. Third, teachers may shift between different socioeconomic areas, thus teaching brighter or duller students on average, and attributing differences to the shift. Fourth, teachers's concepts of intelligence may change with time and many may not hold the notion of general intelligence. Fifth, teachers are not good at identifying some very bright students, identifying as bright only the cooperative, the motivated, and those good at school work (Howard, 1991). Finally, students may be changing in many other ways, masking signs of a rise. One such factor is decreasing motivation to learn. School performance depends heavily on cumulating knowledge, and the effects of poor motivation may snowball over a school career.

However, no one actually has asked a sizeable sample of teachers. Here, I asked teachers, who had taught in Australian schools for at least two decades, of their perceptions of any changes in various student characteristics. Now, raw IQ scores are rising in Australia, too (Flynn, 1987; Tasbihsazan, Nettlebeck & Kirby, 1997), and Australian chess players have been reaching high performance levels at progressively younger ages (Rogers, 1999). In 1999, a thirteen year old won the NSW state chess championship. A 20-year span should be enough for teachers to note a rise. A 30-year span would be better, but preliminary work suggested too few respondents.

I also requested additional information. Given the different ideas about intelligence that teachers may hold (as do researchers in intelligence: see Howard, 1993), I asked about perceptions of various aspects of ability and attitudes. Some theorists suggest a perceived distinction between academic and practical intelligence (or *nous*) (Neisser, 1976; Sternberg & Wagner, 1986). Perceptions of one might be affected by declining motivation for school work and other factors but the other might not be. I also asked about their perceptions of motivation changes.

5.1. Method

The sample consisted of public high school teachers who had begun teaching in 1979 or earlier, and currently were teaching in greater metropolitan Sydney, which stretches from Newcastle to Wollongong and includes most of the state's population. The state education department would not permit teachers to be contacted directly, only allowing me to contact and request school principals to pass questionnaires on to eligible teachers. Participation by principals was completely voluntary. The sample therefore may be biased in various ways. Many eligible teachers may not have participated and many principals may not have passed questionnaires on. However, there was no other way to gather data. The data do represent perceptions of a sizeable sample.

Questionnaires were sent with a cover letter to all public high school principals in the region with a request to pass them on to teachers in their school who had begun their first full time job in 1979 or earlier, and then to return all questionnaires in the enclosed stamped, self-addressed envelope. The cover letter briefly explained the study's purpose and asked each principal not to reveal it until all eligible teachers had completed the questionnaire.

The questionnaire stated that the aim of the study was to get some idea of teachers's perceptions of any changes over the last two decades in the abilities of school pupils in year 10 and under (about ages 15 or 16 years down to 11 or 12). The usual school leaving time had been year 10 in Australia but since 1983 the proportion of students going on to year 11 has doubled. The questionnaire stated that the survey only pertained to students under year 11 and that the only interest was in the teacher's perceptions. The questionnaire asked what year they had begun teaching ("year of first full-time job") and then featured questions all couched in one basic form, "In general, do you believe that the [ ] of students has significantly increased, decreased or has stayed about the same since around 1979".

In successive questions, the brackets had a different insert; which were:

1. "Average general intelligence".
2. "Average level of students's reading and writing skills".
3. "Average level of general knowledge about the world".
4. "Average level of students's street-smartness (e.g. practical *nous*, ability to deal with practical matters)".
5. "Average level of ability to do school work".
6. "Average level of motivation to do school work".

Each question had three alternatives; "increased", "decreased" or "stayed about the same". The questionnaire concluded with an open ended question ("Do you have any personal observations or comments about any perceived changes in the average abilities of students in general over the last two decades?").

5.2. Results and discussion

Of 198 schools contacted, 68 principals returned a total of 316 questionnaires, two principals wrote declining to participate, and 128 principals did not respond at all. The reasons for non-response are not clear, but non-responders were not followed up because participation was voluntary. Ten questionnaires were discarded because they were incompletely filled out or the year stated as the start of teaching was later than 1979.

Table 2 presents the percentage circling each alternative. Perceptions were fairly consistent for some questions, though spread out on others. Most do not perceive that general intelligence is rising. Only 10.46% reported perceiving that students on average were more generally intelligent, with 73.85% saying that average intelligence was about the same. Interestingly, most (63.73%) reported perceiving an increase in practical ability and most (65.03%) that motivation had declined.

The added comments mostly concerned perceptions of declining student motivation: (1) "... students ... lack interest in school work and expect and demand to be entertained"; (2) "... changes have produced a generation that ... lacks self-discipline, self motivation. They do not value education and learning".

Table 2
Percentage of surveyed teachers reporting perception of change since 1979[a]

	Increased	Stayed same	Decreased
General intelligence	10.46	73.85	15.69
Reading and writing skills	22.54	35.30	42.16
General knowledge	38.24	26.79	34.97
Ability to do school work	14.71	40.85	44.44
Street smartness (practical *nous*)	63.73	26.79	9.48
Motivation	9.48	25.49	65.03

[a] $n=306$.

Some commented on declining motivation and added that they felt ability had not changed: (3) "There appears to be a definite decline in students's general motivation and willingness to learn. I feel the abilities and capabilities of students have not changed significantly but on average students are much less motivated to achieve ..."; (4) "Our best students are as good as those in previous decades, but there is a significant reduction in motivation to work at the lower end"; (5) "Abilities are the same, interest and motivations are different. When motivated, students are curious, smart and express ideas well"; (6) "1999 students are no more or less intelligent than 1979 students ... 1979 students appeared to derive motivation to learn from external sources e.g. parental expectation-1999 students need to supply their own motivation ..."; (7) "I feel their abilities have remained the same but the relevance of study to their lives seems to have diminished"; (8) "I detect very little difference in raw ability, but preparedness to work in class seems to be worse"; (9) "The ability is the same, the motivation to achieve has changed"; (10) "Ability has not changed but motivation has declined"; (11) "For the better students, most things have stayed the same or increased whilst for the middle to lower ability students most have decreased, particularly ability and motivation to do school work". Some perceived worsening literacy; (12) "Standards are definitely much lower in areas such as grammar-this is across the board, bright as well as poor students"; (13) "Students have much more limited vocabularies in written communication. Have lower level of fluency in written communication skills generally; e.g. grammatical correctness ... general knowledge is much more limited — not many read newspapers or even watch TV news ... Motivation for many is definitely down, and this becomes more marked as they progress from year 7 to year 10".

A few commented on increased street smartness: (14) "I believe their street smartness has resulted from exposure to more things in the real world ... Because they are exposed more to the world through information technology, they are becoming more intelligent"; and another said (15) "Some students have increased their level of ability to play the system".

This survey has inevitable methodological limitations. We do not know exactly how representative the sample is and those working in the system for several decades may differ in many ways from those who leave earlier. The span is only 20 years. However, it does show that most teachers surveyed do not perceive that general intelligence is rising but most do perceive that practical ability is. They do see at least one change in an ability evidently not affected by the decline in motivation to do school work, which may affect their perceptions of academic intelligence.

6. General discussion

The results may be summarised as follows. First, the prevalence of mild mental retardation apparently has been declining. Second, players have been reaching high performance levels at various intellectual games at progressively earlier ages, particularly in chess, but to a lesser extent in bridge and go. Third, overall scientific productivity is rising, despite some evidence that the top talent is shifting elsewhere. Fourth, most Australian teachers surveyed here do not perceive that general intelligence and ability to do school work is increasing, but possibly because of declining student motivation. They do perceive a rise in practical ability, which may or may not partly be due to rising *g*. Together, these indicators give more data to inform the debate and on balance most are consistent with rising *g*.

One argument by Flynn against rising *g* is that projecting gains backwards would mean that many people born early this century would be considered retarded today. This argument perhaps may be answered by hypothesising that several factors together are at work. First, as Flieller (1999) suggests, the IQ gains partly may be due to faster cognitive development, coinciding with accelerated physical development due to better diet and health. Second, the IQ gains probably partly reflect increasing test sophistication. Much practice doing tests can add several IQ points, with proportionately greater gains at higher intelligence levels (Kulik, Kulik & Bangert, 1984). Interestingly, if *g* is rising, then more and more children would reach higher *g* levels and benefit more from the test practice they get in schools, extending the IQ gains further and elongating the spread of raw test scores. Third, Flynn may be overestimating the average population intelligence in past centuries and the amount of *g* needed to function in an agricultural society. Humans have much genetic programming for normal everyday life tasks (such as propensities to quickly learn a language and social skills) and drawbacks of low *g* may only become evident with arbitrary, unnatural tasks, such as school learning. The phenomenon of "six hour retardation" mentioned earlier suggests that people diagnosed as retarded by IQ tests may have trouble with school work but function adequately even in a technological society. After school, they "disappear into the population". Indeed, rightly or wrongly, rulers and political writers in past centuries have expressed contempt for the abilities of the masses. When cars were invented, some stated that few people had the intellectual capacity to learn to drive them. Such comments are rare today.

Finally, another factor could be that the relationship between *g* and raw IQ test score almost certainly is not linear. (Raw test scores are affected by many factors, such as motivation and knowledge, but, for the sake of argument let us assume these variables have no effect.) Flynn essentially is assuming a linear relationship, where x units of *g* always equal y units of raw IQ score. Indeed, the relation between raw score and scaled IQ score is not linear. Raw scores are transformed to ensure a normal distribution and getting one more item right might add, say two more IQ points for a person at one level but only one point for someone at another. At certain *g* ranges, small increments in *g* may produce larger increments in raw IQ scores. If many more people are reaching higher *g* levels, when scores are normalised, the distribution may actually be getting stretched. So, it is possible that a combination of non-linearity and the other factors and effects of many other variables such as motivation and improved visuospatial ability may well answer this argument. IQ tests are imperfect instruments at best.

Further research could look at as many other indicators as possible. Researchers might also try to find ways to gauge the size of any *g* rises and whether they are distributed evenly over the whole intelligence continuum. Teasdale and Owen (1989) suggest that the rise is concentrated below the mean but the present study suggests the upper range is being affected too. Finally, researchers should look further at devising a physiological measure of *g*. When the human genome project identifies the genes for *g* and how they interact with environmental factors, this may be possible.

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