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Sexually dimorphic traits (digit ratio, body height, systemizing–empathizing scores) and gender segregation between occupations: Evidence from the BBC internet study

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ABSTRACT

The proportion of women (PW) across occupations shows considerable variation. Here we hypothesize that occupational segregation could be moderated by the effect of testosterone (T), leading individuals to gender-typical choice of occupation. To test this, we examined the relationship between PW across 22 occupations and three putative correlates of T (the 2nd to 4th digit ratio [2*D*:4*D*], a supposed correlate of prenatal T [PT]; body height, a possible correlate of adult T [AT]; and a systemizing–empathizing score [SQ–EQ], a putative behavioural correlate of PT and AT) in a large internet survey. PW varied from 17% (Engineering/R&D) to 94% (Homemaker) per occupation. Compared to participants in female-typical jobs, participants in male-typical jobs tended to have low right hand 2*D*:4*D* and low right–left hand 2*D*:4*D* [Dr-l] (higher PT, women only), were taller (higher AT, men and women), and had higher SQ–EQ scores (higher PT and AT, men and women). With regard to women, the relationships for Dr-l and SQ–EQ (but not body height) remained significant when Whites only were considered. We conclude that in women Dr-l, and SQ–EQ are related to occupational segregation, suggesting that high PT and AT are found in women who are in male-typical occupations.

1. Introduction

Some occupations have an excess of women and others an excess of men. Thus the proportion of women per occupation (PW) may vary considerably from male-typical occupations such as engineering to female-typical occupations such as homemaker. Gender segregation between occupations may have its roots in social factors that lead to discrimination or absence of female role models, and this may be one influence that leads to variation in PW (Petersen & Morgan, 1995).

In the last two decades there has been movement in the US and UK towards a more even sex ratio (PW = 0.5) in many occupations (Weeden, 1998; Wells, 1999), but in some such as the female-dominated caring professions and in male-dominated engineering there has been little change (Govier, 2003). This situation may in part arise because of the influences that determine women's individual choices. For example many women are obliged to take time out to have children. Consequently they may choose an occupation that has little or no financial penalty for breaks in employment, that is flexible in the provision and accommodation of maternity leave, one in which the work is not so physically demanding as to affect pregnancy, or even one in which injury is unlikely to affect their role of caregiver to children. Such hypotheses have been tested, but with mixed results (DeLeire & Levy, 2004; England, 1982, 1985; Polachek, 1981, 1985).

In this present study we stress a biological explanation by arguing that the occupational sex segregation could arise because men and women differ biologically, even prenatally. Testosterone (T) is a sex steroid hormone and males produce twice as much as females, even in the womb. Prenatal T (PT) has been shown in animal research to cause organisational changes in the brain while adult T (AT) may have activational effects, such that high PT is associated with higher systemising (Auyeung et al., 2006) and lower empathizing ability (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004; Chapman et al., 2006). Both PT and AT influence an individual's 'brainsex' and the resulting variation in brain masculinization/feminization could, at least in part, explain gender segregation across occupations (Baron-Cohen, 2003; Govier, 2003). Here we test this model by relating PW per occupation to (i) the ratio of the length of the 2nd and 4th digits (2*D*:4*D*), a putative correlate of PT, (ii) height, a possible correlate of AT, and (iii) a measure of the relative strength of systemizing and empathizing (systemizing–empathizing scores), a putative correlate of PT and AT.

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Digit ratio shows sex differences such that males have, on average, lower 2*D*:4*D* ratios than females. This sexual dimorphism is highly conserved and is found not only in humans but throughout the primates (Manning, 2002, 2008; Manning, Scutt, Wilson, & Lewis-Jones, 1998; Nelson & Shultz, 2010). In humans it has been suggested that 2*D*:4*D*, and particularly right hand 2*D*:4*D* and the difference of right minus left hand 2*D*:4*D* (Dr-l), are negatively related to PT (Manning, 2002; Manning et al., 1998). Across populations both 2*D*:4*D* and Dr-l are sexually dimorphic (Manning, Churchill, & Peters, 2007; Manning, Stewart, Bundred, & Trivers, 2004). The sex difference is seen in young children (Manning et al., 2004), arises in utero as early as nine weeks (Galis, Ten Broek, Van Dongen, & Wijnaendts, 2010; Malas, Dogan, Evcil, & Desdicioglu, 2006), and the strength of the sexual dimorphism in infants is strongly related to the sex difference in adults (McIntyre, Ellison, Lieberman, Demerath, and Towne, 2005; Trivers, Manning, & Jacobson, 2006). Children with congenital adrenal hyperplasia, a condition in which high PT is produced, have lower 2*D*:4*D* than typical controls (Brown, Hines, Fane, & Breedlove, 2002; Ciumas, Linden Hirschberg, & Savic, 2009; Okten, Kalyoncu, & Yaris, 2002; but see Buck, Williams, Hughes, & Acerini, 2003). Right hand 2*D*:4*D* and Dr-l are positively correlated with complete or partial T insensitivity as determined from the structure of the androgen receptor gene (Berenbaum, Bryk, Nowak, Quigley, & Moffat, 2009; Manning, Bundred, Newton, & Flanagan, 2003) and right hand 2*D*:4*D* was found to be negatively correlated with foetal testosterone:oestrogen ratios obtained from amniocentesis (Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004).

With regard to AT, body height is strongly sexually dimorphic across all human groups such that males are on average taller than females (Gray & Wolfe, 1980). The sexual dimorphism in height is not strongly developed until puberty and is largely dependent on growth of the long bones (Antoszewska & Wolański, 1992). It is known that androgen receptors are present in osteoblasts and androgen is metabolised in bone (Lorentzon, Swanson, Andersson, Mellström, & Ohlsson, 2005). Furthermore, observations in androgen-resistant animals show the sex differences in bone are dependent on functional androgen receptors (Vanderschueren & Bouillon, 1995).

Finally, men, on average, score higher than women in understanding and building systems, while women are better able to identify other people's emotions than are men. Thus men score higher on the Systemizing Quotient (SQ) and women score higher on the Empathizing Quotient (EQ) (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003) and the same pattern of sex differences is seen on the child versions of these psychological measures (Auyeung et al., 2009). There is evidence that PT (as measured from amniotic fluid) is positively related to systemizing (Auyeung et al., 2006) and negatively related to empathizing (Chapman et al., 2006; Knickmeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006).

Based on the reported associations of PT, 2*D*:4*D* and SQ–EQ and AT and body height, we examined the relationship between these sexually dimorphic traits and PW across a number of occupations in participants in a large internet sample. Our prediction was that measures of PT and AT would be negatively correlated with PW. With regard to our correlates of T this would mean that right hand 2*D*:4*D* (but not left hand 2*D*:4*D*) and Dr-l would be positively correlated with PW, while body height and SQ–EQ would be negatively related to PW.

2. Methods

Participants were drawn from a large Internet survey (the BBC Internet study) of cognitive and behavioural sex differences, hosted by the BBC Science and Nature Website. Details of the study and patterns of 2*D*:4*D* within the study are given in Reimers (2007) and Manning et al. (2007), respectively. Data were collected between January and May 2005. Briefly, the study took 30–40 min to complete, and comprised questions about demographics, personality, sexuality and sexual behaviour, social attitudes and behaviours, along with cognitive tests and physical characteristics such as the 2*D*:4*D* ratio. There were six blocks, taking between 3 and 6 min each to complete. Participants completed the blocks in sequence and were able to stop and return to the study at any point later.

The first questions in the study were gender (male/female) and age (0–99) for which a value had to be entered in order to continue. Responses to all other questions were optional. Occupation and ethnicity appeared on the first page with gender and age, both with dropdown menus, from which participants could choose one of 25 categories for occupation and one of seven categories for ethnicity (Asian/Asian British, Black/Black British, Black other, Chinese, Middle/Near Eastern, Mixed ethnic, White).

In the second part participants provided self-measured finger lengths following the methodology of Manning et al. (1998); see also Caswell and Manning (2009). After viewing a diagram of the hand, they were given instructions as to how to measure their index finger and ring finger on the palm-side of the right and left hand. The participants were asked to measure finger lengths with a ruler and to report lengths to the nearest millimetre using dropdown menus, with values between 10 and 100 mm in 1 mm increments (Reimers, 2007). Participants were also asked to report their body height.

In the third part there were 10 questions selected from the full EQ and ten from the full SQ (Baron-Cohen et al., 2003). The selected questions had the highest sex difference in the control data reported in Wheelwright et al. (2006). The scoring options were from left to right: definitely agree (DA), slightly agree (SA), slightly disagree (SD), and definitely disagree (DD). This was scored positively or negatively (positively: DA and SA = 0, SD = 1, DD = 2). An SQ and EQ score was calculated by summing across the 10 questions. Full details of the items and the scoring were given in Manning, Baron-Cohen, Wheelwright, and Fink (2010).

Web studies often attract a large sample. However, there are disadvantages. Participants in Web studies usually have higher levels of education than non-participants and this was the case for the Study with high proportions of participants reporting they had post-graduate degrees (13.5%) or had attended a University (35.5%) (Reimers, 2007). Inaccurate self-measurement may also be of concern. However in the case of the Study, tests of consistency of 2*D*:4*D* with that of experimenter-measured studies gave similar results (e.g., in the sex-dependent and ethnicity-dependent patterns of 2*D*:4*D*; Manning et al., 2007).

3. Results

There were 255,116 participants who completed the entire study of whom 47.3% were female. White participants made up the greatest proportion (84.%), followed by Asian (6.3%), mixed ethnicity (3.9%), Chinese (2.2%), Middle/Near Eastern (1.2%), Black/Black British (0.8%), Black (0.8%). The analysis was restricted to respondents who were 18 years and older. Inspection of the 2*D*:4*D* data showed extreme values varying from 0 to 10. We excluded such outliers by considering a range from 0.80 to 1.20, as recommended from a comparison of self- and experimenter-measured 2*D*:4*D* (Caswell & Manning, 2009). There were a total of 199,021 participants (89,506 women) available with occupational choices. The occupations are arranged in ascending order of PW in Table 1. PW varied from 17% for male-dominated Engineering/

Table 1
Proportion of women (PW) per occupation and mean right hand 2*D*:4*D*–left hand 2*D*:4*D* (Dr-l), mean body height (m), and mean SQ–EQ in a sample of men (M) and women (W). The total sample consisted of 199,021 participants and included 89,506 women.

Occupation			Men			Women		
	n	PW	Dr-l	Height	SQ–EQ	Dr-l	Height	SQ–EQ
Homemaker	5141	0.94	−0.002	1.784	3.898	0.003	1.648	−3.497
Administration	13,075	0.75	0.001	1.793	3.738	0.003	1.651	−3.271
Healthcare	5408	0.70	−0.0002	1.789	3.237	0.002	1.650	−3.917
Personnel	949	0.63	0.001	1.790	3.535	0.004	1.655	−3.116
Education	12,500	0.63	−0.001	1.790	4.144	0.002	1.652	−3.252
Customer service	6071	0.56	−0.001	1.789	3.553	0.003	1.652	−2.935
Medical/science	7739	0.54	−0.001	1.790	5.194	0.001	1.655	−1.827
Legal	2604	0.53	0.0002	1.798	5.960	0.002	1.657	−1.523
Student	45,419	0.49	−0.0002	1.794	5.039	0.002	1.654	−1.999
Accounting/finance	8075	0.49	−0.0003	1.795	5.754	0.001	1.652	−1.450
Media	6116	0.48	−0.0004	1.796	3.361	0.001	1.666	−2.494
Sales/market/advert	8430	0.46	−0.0002	1.798	4.335	0.003	1.659	−2.615
Purchasing	640	0.44	−0.003	1.798	5.131	0.003	1.651	−1.983
Unemployed	5587	0.44	−0.00005	1.786	3.841	−0.0001	1.650	−2.013
Prof. services	6952	0.43	0.00001	1.793	4.833	0.001	1.657	−2.526
Business develop.	1633	0.38	−0.002	1.794	5.158	0.002	1.653	−1.317
Government/military	5333	0.36	−0.0002	1.793	5.430	0.002	1.654	−1.364
Gen. management	3326	0.36	−0.001	1.798	5.140	0.001	1.658	−1.948
Retired	3289	0.35	−0.0003	1.779	4.893	0.002	1.644	−1.536
Consultancy	3802	0.31	0.00002	1.797	5.771	0.001	1.660	−1.691
Executive/snr manag	3326	0.27	−0.001	1.797	5.740	−0.001	1.656	−1.337
Manufacturing/oper.	2703	0.23	−0.003	1.789	5.270	−0.003	1.654	−1.073
IT	24,124	0.18	−0.001	1.793	6.050	0.002	1.654	−0.396
Skilled labour	4477	0.17	−0.002	1.793	4.845	−0.001	1.655	−1.397
Engineering/R&D	12,302	0.17	−0.001	1.791	6.694	0.002	1.657	1.064

R&D to 94% for the female-dominated Homemaker category. Means for male and female digit ratios (for brevity we give Dr-l only), height and SQ–EQ are also given in Table 1.

A comparison of male/female means within occupations showed the expected sex differences (paired *t*-tests females [*x*] − males [*y*]). Considering 2*D*:4*D*, there were lower values in males compared to females (right hand 2*D*:4*D* $x - y = 0.01$, $t = 19.98$, $p < 0.0001$: left hand 2*D*:4*D* $x - y = 0.007$, $t = 13.88$, $p < 0.0001$: Dr-l $x - y = 0.002$, $t = 7.18$, $p < 0.0001$). Considering body height, women were shorter than men $x - y = -0.14$, $t = 180.09$, $p < 0.0001$. Finally, considering SQ–EQ, this was higher for males $x - y = -6.85$, $t = 63.81$, $p < 0.0001$).

Three occupation categories were not informative ('Unemployed', 'Retired', and 'Student') since these contained individuals who might have worked in any occupation. We therefore removed these three categories from the analysis, and considered the participants in the remaining 22 occupations. With very large samples even very weak effects can be significant. Therefore, we used mean digit ratios, height and SQ–EQ scores per occupation and sex in the analyses. Thus the relationships had a sample size of 22 and significant correlations would have to have large effect sizes.

There were positive associations between digit ratios and PW, and negative associations between height or SQ–EQ and PW, and when we found these we used one-tailed significance tests. The correlations for digit ratios were stronger for women, with significant associations between right hand 2*D*:4*D* and Dr-l (but not left hand 2*D*:4*D*) and PW (Fig. 1a and b). There were no significant correlations between 2*D*:4*D* and PW for men. The relationships between body height and PW in men and women were negative and stronger than those for digit ratios (Fig. 2), and there were very strong negative correlations between SQ–EQ and PW in both sexes (Fig. 3; Table 2).

A multiple regression analysis for females only with PW as dependent variable and Dr-l, height, and SQ–EQ as independent variables showed that Dr-l remained positively related to PW (beta = 0.27, $t = 2.39$, $p < 0.01$) and height (beta = −0.20, $t = 1.83$, $p < 0.05$) and SQ–EQ (beta = −0.70, $t = 5.93$, $p < 0.0001$) remained significantly negatively related to PW. A similar test for males gave no significant relationship for Dr-l (details not shown). There were ethnicity effects on 2*D*:4*D* in the Study (Manning et al., 2007).

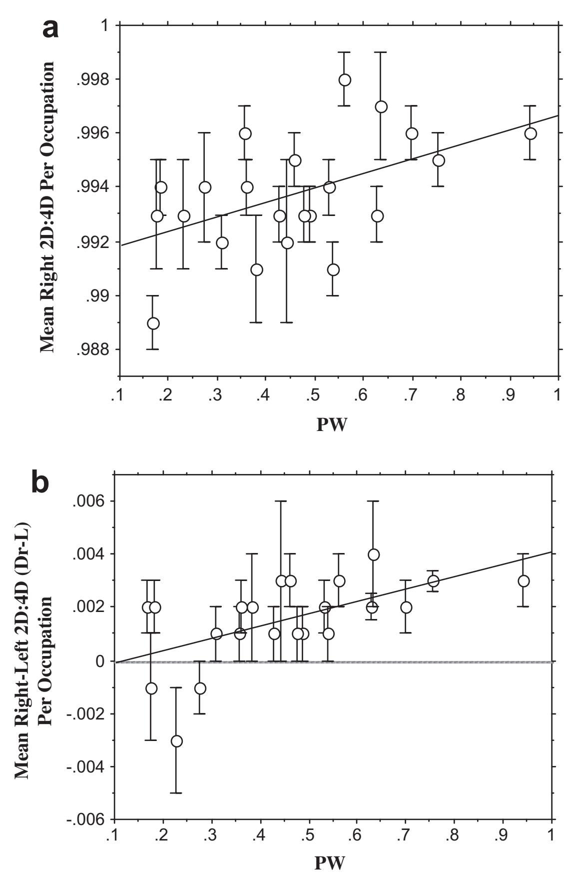

Fig. 1. The associations between the proportion of women (PW) per occupation and mean right hand 2*D*:4*D* ± SE bars (a) and mean Dr-l ± SE bars (b) per occupation in a sample of 22 occupations and 89,506 women. The formula for the line in A is $y = 48.304x - 47.546$, $r^2 = 0.26$, and in B it is $y = 72.95x + 0.342$, $r^2 = 0.34$.

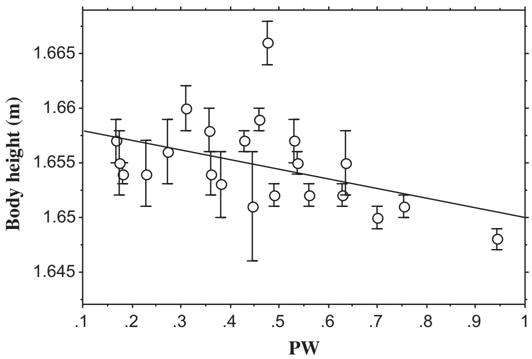

Fig. 2. The relationship between PW and height in a sample of 89,506 women from 22 occupations. The formula for the line is $y = -4.764x + 0.173$, $r^2 = 0.20$.

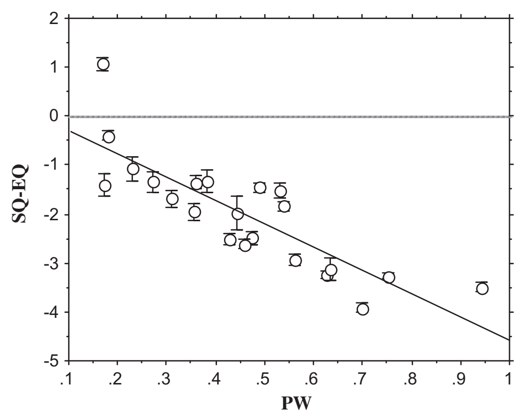

Fig. 3. The relationship between PW and SQ–EQ in a sample of 89,506 women from 22 occupations. The formula for the line is $y = -4.764x + 0.173$, $r^2 = 0.70$.

Table 2
Product moment correlations (r) between proportion of women per occupation (PW) and means for right hand 2*D*:4*D*–left hand 2*D*:4*D* (Dr-l), body height, and SQ–EQ for 22 occupations. One-tailed p-values remained significant also when tested two-tailed.

Trait	r	p
Men		
2*D*:4*D* right	0.09	0.35
2*D*:4*D* left	−0.07	0.77
Dr-l	0.30	0.09
Height	−0.44	0.02
SQ–EQ	−0.71	0.001
Women		
2*D*:4*D* right	0.51	0.01
2*D*:4*D* left	0.09	0.34
Dr-l	0.58	0.003
Height	−0.45	0.02
SQ–EQ	−0.84	0.0001

Whites were the most numerous ethnic group and unlike the other ethnicities they were represented in large numbers in all the occupations. Therefore, we considered Whites only in a multiple regression and found that Dr-l (beta = 0.26, $t = 1.77$, $p < 0.05$) and SQ–EQ (beta = −0.63, $t = 4.41$, $p < 0.001$) remained significantly related to PW but height did not (beta = −0.11, $t = 0.82$, $p = 0.21$).

4. Discussion

In women, two putative negative correlates of PT, right hand 2*D*:4*D* and Dr-l, were positively related to PW across 22 occupations. This suggests that women with high PT are more likely to work in occupations that are male-dominated, while women with low PT are more likely to work in occupations that are female-dominated. The mean Dr-l explains about 30% of the variance in PW in the overall data and in the White only sample. There were no significant links between 2*D*:4*D*, Dr-l and PW in men. This may be because of ceiling effects in 2*D*:4*D* in men.

The 2*D*:4*D* result supports the hypothesis that PT has an organising effect on the brain that in turn affects female choice of occupation. A number of studies have shown that gender dependent traits such as performance in dichotic listening tasks, synonym generation and spatial tests are correlated with some occupational choices. This applies within-sex such that male-typical scores have been reported among women in male-typical occupations and female-typical performance among women in female-typical occupations (Govier, 2003; Govier & Bobby, 1994; Govier & Feldman, 1999).

With regard to 2*D*:4*D*, there is evidence that low 2*D*:4*D* is linked to success in financial activities involving substantial risk. Coates, Gurnell, and Rustichini (2008) reported that high-frequency financial traders with low 2*D*:4*D* showed higher profits than traders with high 2*D*:4*D*. In addition, low 2*D*:4*D* and high circulating T levels are related to low levels of risk aversion and choice of risky careers in finance in women but not men (Sapienza, Zingales, & Maestripieri, 2009).

Our data are the first to show that in a range of occupations among women, male-typical 2*D*:4*D* is linked to male-typical occupations and female-typical 2*D*:4*D* to female-typical occupations. In common with Sapienza et al. (2009) we did not find the same effect in men. This may be because male PT is in general high and there could be a threshold over which additional increases in PT do not give further effects on 'brainsex' or on occupational choices. With regard to the female 2*D*:4*D* and PW correlations we think the most obvious explanation of our results is that PT influences women's preference for aspects of particular jobs. It is already known that amniotic PT influences gender-typical play (see for review Hines, 2008) and gender-typical interests (Auyeung et al., 2009). However, we wish to underline that the effect of PT could be amplified by social factors, such as employers' perceptions of applicants' suitability for a job or the effects of being absent from the labour market due to having children. It is of note that there have been recent changes in PW in some occupations but not in others. This may be because preferences for the former are less strongly influenced by PT than for the latter.

We found sexually dimorphic measures other than digit ratios were significantly related to PW. Women in male-typical jobs tended to be taller than women in female-typical jobs. This is likely to reflect height being a positive correlate of AT (Deady & Law-Smith, 2006). Ability/interest in systemizing is associated with high PT (Auyeung et al., 2006) and high empathizing scores is associated with low PT (Chapman et al., 2006). We found that high SQ–EQ scores were negatively associated with PW. Among females the correlations between Dr-l, height, SQ–EQ and PW were independent of one another. However, considering the most common ethnic group only (Whites) in a multiple regression (independent variables Dr-l, height, SQ–EQ and dependent variable PW) Dr-l and SQ–EQ remained significantly linked to PW but body height did not. This suggests that height is not a strong predictor of PW whereas PT measures are.

There are limitations to our study. Self-reports of finger length and height may contain inaccuracies. However, the sex and ethnic differences in 2*D*:4*D* found in the Study are similar to those reported elsewhere (Manning et al., 2007), and self-reported height correlates strongly with experimenter-measured stature (Himes & Roche, 1982). In addition some occupation categories may have been too broad (military and civil service occupations could have been split) and could have included further information such as first occupation. These issues with regard to occupation should be addressed in future studies.

In conclusion, our data support the hypothesis that, over and above any social factors, biological markers are associated with the type of occupation that women end up in. That is, right hand 2*D*:4*D* and Dr-l, are related to PW across a wide range of occupations. Scores on the EQ and SQ have previously been found to be better predictors than an individual's sex or whether a student studies sciences or humanities (Billington, Baron-Cohen, & Wheelwright, 2007), leading to the conclusion that one should not focus on whether an individual is male or female (which would be potentially sexist) but rather on their individual make-up (their hormone levels or their cognitive profile). There is accumulating evidence that 2*D*:4*D* and Dr-l are correlates of androgen sensitivity (Berenbaum et al., 2009; Manning et al., 2003, 2004) and levels of PT. This leads to the conclusion that high PT in women is related to their choice of male-dominated careers. In addition height and SQ–EQ scores are negatively related to PW, supporting the view that high PT and AT combine to influence the choice of occupations with low PW.

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