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**Engineering and Autism:
Exploring the Link Further. A Reply to
Wolff, Braunsberg, and Islam.**

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Dear Editor

We are grateful for the opportunity to reply to the 3 letters which discuss our article “Is there a link between engineering and autism?” ([Autism](#), Vol 1.1., 101-109). Below we address each of these letters in turn.

Dr Sula Wolff’s letter

We think Dr Wolff’s points are valuable. Our response focuses on each of her arguments, itemised here:

1. The occupation of engineering “was in fact quite rare among the relatives of the different cohorts of children studied..”.

Is engineering rare? This is of course a relative term. Our point was that whilst in all other samples engineering occurred in only about 5% of fathers (or grandfathers), in the National Autistic Society (NAS) sample it occurred more than twice as often in both the fathers and grandfathers. This was strongly significant.

To put it starkly: 1 in 8 of the fathers of children with autism is an engineer, whilst only 1 in 20 fathers of non-autistic children is an engineer. Considering the number of occupations available for them to go into, 1 in 8 seems to us to be a very high rate, and is in need of explanation.

Our explanation is in terms of this occupation being (one of several) natural choices for someone who has relative strengths in “folk physics” along with relative weaknesses in “folk psychology” - our proposed characterization of the broader cognitive phenotype of autism.

2. “there must be many uncharted steps between an aptitude for *folk physics* and working as an engineer.”

It is true that we have not demonstrated that all engineers have an aptitude for folk physics, but we think this is uncontroversial, in that engineering involves working with physical objects and physical systems.

Engineering is not synonymous with folk physics, it is simply a clear example of it. It is true that many people with an aptitude for folk physics might not become engineers. They might go into other occupations which are object-centred, such as architecture/surveying, physics, or even mathematics. But these are very low frequency occupations in any population. Hence our decision to look at engineering.

Note that we are not saying that most engineers have a weakness in folk psychology. This does not follow at all from what we are saying. All we are saying is that most engineers by definition have good folk physics.

On to Dr Wolff's central point:

3. “there are overall differences between the groups... when occupations listed are aggregated into... (occupational classes I-V)”.

Again, she is right that the groups differ in terms of occupation classes I-V. Presumably these reflect social, economic, and/or educational class differences. Our point in the article was that we doubt these class differences can explain the preponderance of engineers in the NAS sample. Let us clarify why we believe this.

Dr Wolff provides a useful Table with percentages of parents from each sample aggregated into each of the occupational groups I-V. However, she only does this for the NAS, Normal, and Down's groups¹. As she shows, the NAS have more fathers working in occupation groups I and II than do the normal or Down's groups. We were aware of this potential bias, which is why, before submitting the data for publication, we gathered data from another group who were members of a charity similar to the NAS: in this case, the Tourette Syndrome Association (TS). Dr Wolff does not include them in her Table, but they are crucial, as can be seen in Table A here:

Table A: Occupational Groups I-V: NAS vs TS

<i>Occupational Groups</i>	<i>NAS</i>	<i>TS</i>
I and II	61.6 ² %	50%
III	33.0%	45%
IV and V	5.2%	2.5%

Chi Square tests conducted on these data (raw numbers) show that the NAS groups do not differ from the TS groups in terms of occupation groups I and II (Chi = 1.71, 1df, p = 0.192), or occupation group III (Chi = 1.98, 1df, p = 0.159), or occupation group IV-V (Fisher's Exact Probability Test, p = 0.2).

¹ In her Table, columns do not all add up to 100%. This may lead to some biases in this comparison.

² In her Table, the figure here is given as 61.1%, though in checking this we find that it should be 61.6%. Hence this discrepancy.

So, even though the NAS sample is biased towards occupation groups I-II, so is the TS sample, when either of these are compared to the other samples. By itself this therefore cannot explain the NAS-engineering link. Rather, all this shows is that the sorts of parents who join societies such as the NAS and the TS Association are biased towards the professions. It underscores all the more why we needed to include the TS as a critical control group in our study.

Note also that the idea that the excess of engineers in the fathers and grandfathers of children with autism could reflect some “professional” or social class bias does not stand up as an explanation, since there were other professions (e.g., law, or social work) where there were no group differences between the NAS sample and the control groups.

4. “It is also possible that somewhat more general intellectual ability and intellectual interests might account for their findings.”

The implication here is that “general” intelligence might account for the link found. We cannot see how this might hold, since we have no evidence that the parents in the NAS sample differ in terms of “general” intelligence from parents in all of the other samples.

Rather, we think the results are most easily explained in terms of a “specific” intellectual factor, namely, that fathers and grandfathers of children with autism have strong interests in the world of physical objects (things) rather than the social world (people).

As mentioned under point 2, above, we do not want to claim any special link between engineering per se and autism, since a set of related occupations may require strong interests in the world of things rather than people.

We thank Dr Wolff for her thoughtful letter and hope this response clarifies the interesting points she raises.

Hannelore Braunsberg’s letter

Again, we are grateful for Ms Braunsberg’s careful questions, which prompt us to supply below additional statistical analysis than was presented in the original paper. Her questions are very appropriate. Again, her concerns are itemised here:

1. “It is not clear whether chi-square tests were performed on all categories for NAS parents versus other groups...”

We did not perform chi-square tests on all occupational categories, because of the number of comparisons that this would have entailed. As we are sure Ms Braunsberg will be aware, multiple statistical comparisons are to be avoided so as to minimize the risk of results found to be significant by chance alone. (Carrying out 20 comparisons, for example, each with a significance level set at 0.05, means that one comparison might be significant by chance alone). Instead we carried out a hypothesis-driven comparison, based on our prediction - in this case, about engineering.

However, we were of course aware of the wider issue of needing to check if the NAS fathers (and grandfathers) were over-represented not just in the category of engineering, but in other occupational categories too, since this might reflect sampling biases. To address this, we inspected the data (presented in Table 1 of our original article) to see if there was a higher proportion of fathers from the NAS sample in any other occupation category. We did this by looking across the 4 control groups, and asking for all 18 categories listed: “Are fathers in the NAS group higher than all 4 control groups?”. As will be seen by inspection, engineering is the only category that the proportion of fathers in the NAS sample is substantially elevated, relative to all 4 control groups.

But for completeness, it is worth us listing that the proportion of fathers in the NAS sample was higher than all 4 control groups in 4 other occupational categories: these are shown in Table B, here. None of these are significantly different, statistically.

Table B: Occupations (other than engineering) in which NAS fathers occur at a higher rate than all 4 control groups*.

	NAS	Control	Chi Square	p
Science	5.4%	5.0% (TS)	0.06 (1df)	0.8 (ns)
Accountancy	6.2%	5.0% (TS)	0.001 (1df)	0.97 (ns)
Teachers	7.1%	6.0% (DS)	0.43 (1df)	0.51 (ns)
Clerks	13.5%	11.4% (DS)	1.04 (1df)	0.31 (ns)

* The NAS rate is compared to the next highest control group

Regarding grandfathers, we would caution readers from carrying out extensive statistical analysis on this sample, because comparison data are only available from one control group (TS), which has a much smaller sample size (n = 40) compared to the NAS sample (n = 919). This danger is less important for the fathers, as 4 control groups are available. The grandfather data is interesting in that it shows a trend for both paternal and maternal grandfathers to have elevated engineering rates, akin to what is seen in the fathers. But conclusions about the grandfather data should be considered preliminary pending larger and well-matched comparison data sets being collected. We consider the data from fathers as the primary result in our original paper.

2. What about mothers and grandmothers of children with autism?

Ms Braunsberg rightly asks about mothers and grandmothers of children with autism: did more of these go into teaching, compared to controls? It will be noted that we did not carry out any statistical testing on the data from mothers or grandmothers, for the simple reason that (as Tables 2 and 4 of our original article show), approximately half of mothers in 3 of the control groups, and approximately 40% of all grandmothers, were in the category of “housewife”. This category cannot tell us anything about cognitive skills, even indirectly. We do not know which occupation these women would have worked in if they had had work outside the home. Because of the large proportion of women for whom we had no information apart from knowing they were “housewives”, the data from female family members was left unanalysed statistically. Such data is simply too prone to sample biasing of a variety of kinds to be informative. (For example, many women in the grandmother generation might have been discouraged from working outside the home). The data from female members of the family was nevertheless reported in the two Tables for the sake of completeness, since this had been collected.

3. “... any statistical significance found may suggest the existence of “fortuitous” relationships... and throw some doubt on the conclusions drawn”.

We hope that our reply to the above two points answers this possibility. To reiterate, none of the other occupations showed fathers or grandfathers in the NAS sample to be over-represented with the same order of magnitude as was seen in engineering.

We thank Ms Braunsberg for her thoughtful questions, and for prompting us to give a fuller discussion of the data .

Yakoub Islam's letter

We regret that Mr Islam felt our article contradicted the journal's editorial aims. We understand his worry that some professionals may use this data unjustifiably to marginalise parents. We would strongly oppose any attempt to do this. Sadly, the history of professional involvement in the field of autism has not always been supportive of parents, and we hope those bad old days of parent-blaming are firmly behind us.

It is true that our study leans heavily on the genetic theory of autism, and we do this because the heritability of autism has been estimated to be as high as 90%, based on existing twin studies. Some parents may worry that this is parent-blaming in a new guise. We hope they will be reassured that this is not the case. No-one is to blame for their genes, and no-one should be marginalised because of their genes. Furthermore, at this stage of scientific understanding, it is not at all clear how many genes are involved in the cause of autism, and what these genes are for. It is a strong possibility, for example, that some of the genes that will eventually be discovered to cause autism will also be involved in the development of brain functions responsible for the cognitive strengths or superiority that have been documented (Baron-Cohen and Hammer, 1997, Journal of Cognitive Neuroscience, 9, 548-554). It is also an explicit assumption of our article on the engineering-autism link that parent(s) of children with autism may be excelling in certain fields. Far from feeling blamed, we hope parents will take this research in the spirit intended: to understand better what autism is, how it arises, and how autism can occur in the presence of unusual talents as well as the more familiar difficulties.

Mr Islam is correct to say that jumping from occupations to genetic links is tenuous and that given that occupations are such a broad correlation of behaviour, it would be bad science to assume any link with biological mechanisms. We agree with all of these points, and would not wish to do this. Occupation data is a crude, first-pass approach at asking if there is a "broader phenotype", and far more refined measures will be needed before any conclusions can be drawn. The paper cited above takes this one step further in using laboratory measures, administered under controlled conditions, to try to understand the processes a little more. But even this is a long way from providing a complete causal model.

We agree that it would be foolish to say that coughs cause chest infections, but could not see what the analogy was with our study.

Finally, it may be of interest to read the reaction to our study from a parent of a child with autism who is an engineer. The magazine Professional Engineering has summarized this research, and it generated the following letter:

“.. I took part in his initial survey, owing to the fact my youngest son was recently formally diagnosed, at the age of 4, as being “mildly” autistic...as an academically and professionally qualified engineer, and father of an autistic child, I feel...so little is

known about the “autistic continuum”, that any research... should be actively encouraged. For interest’s sake, my son not only has a father who is an engineer, but both his uncle and grandfather have successful engineering careers.” (K.S. Senior, HQ Logistics Command, Royal Air Force Wyton, Huntingdon, Cambs, *ibid*, p. 42, Volume x, 1996.).

We try our utmost to work in partnership with parents, and hope the above response clarifies this.