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Intrapair Facial Differences in Twins

P.H. Burke

Department of Child Dental Health, School of Clinical Dentistry, Sheffield, UK

Abstract. Annual serial records in the form of facial contour maps were examined for 18 like-sexed twin pairs of near equal zygosity distribution. Zygosity diagnosis was based primarily on hematological reports for 26 of the 36 children and the remainder were diagnosed on a basis of the concordance or discordance of various physical characteristics: standing height, finger print ridge count, tooth size, and hair and eye colour. Thirteen facial parameters were measured on 274 maps. After age correcting and theree-point smoothing, more than 1,150 intrapair differences of individual facial parameters were measured. In general, the dizygotic twin pairs had the larger mean intrapair differences in facial parameters and the monozygotic twin pairs had the smaller intrapair mean differences. The more important facial parameters for distinguishing the two groups were identified and used to calculate a "facial similarity index".

Key words: Intrapair differences, Face, Twins, Stereophotogrammetry

INTRODUCTION

Facial morphology has always been important in twin studies and two-dimensional photography has generally been the method of recording the face qualitatively. Vision records the face stereoscopically and therefore three-dimensionally, allowing a high standard of facial identification by inspection only. However, three-dimensional photogrammetry of the face has been feasible since 1939 when Zeller [25], a cartographer, first used a stereometric camera and plotting machinery to make a contour map of the face. This technique was first used by Thalman-Degen in 1944 to record facial change for clinical purposes [22], and others have followed her example [3,13,23,2].

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The complexity of the plotting machinery has precluded its wider adoption, but a simplified system of clinical stereophotogrammetry was evolved by Beard and Burke [1] and its accuracy measured [4,5]. This method was used to record annually the facial growth of 27 pairs of like sexed twins between the ages of 7 and 19 years in a mixed longitudinal study [7]. It is material which has been abstracted from this study which has been used to examine intrapair differences in facial parameters in 18 pairs of twins of near equal zygosity distribution.

Inspection of the soft tissues of the face by stereoscopic vision has been claimed to be an aid to assessing zygosity in twins [10]. This paper tests this concept by measuring 13 facial parameters and comparing intrapair differences in facial parameter size in MZ and DZ twins.

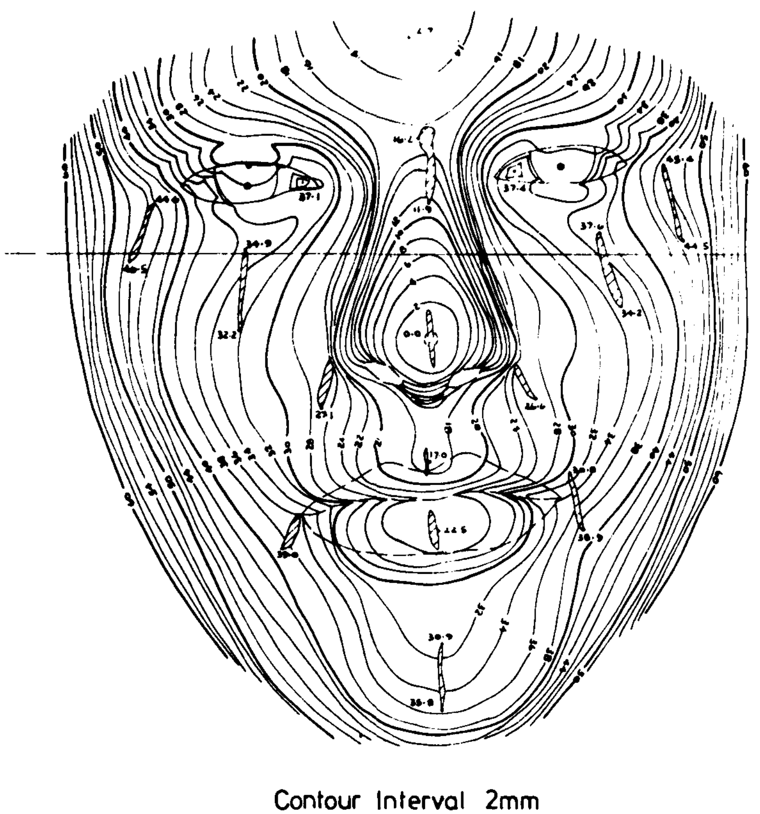

Fig. 1. Contour map of the face, contour interval 2 mm and zero value on tip of nose.

MATERIALS AND METHOD

The 36 like sexed twins included 10 MZ (4 male, 6 female) and 8 DZ (4 male, 4 female) twin pairs. The age range was 9 to 17 years but most of the DZ twins were in the older age range. The zygosity determination was based firmly on hematology, which was available for 26 children. When not available, it was based on fingerprint ridge count, standing height, tooth size, and hair and eye colour. The hematological diagnosis was based on congruence, or lack of it, in 7 groups: AB0, MNSe, P, RL, Lu, K, Duffy (Fy), Kidd (JW). When the diagnosis was given as MZ, the probability was added in percentage terms. In two pairs, parents were also examined, allowing the probability of a correct diagnosis of monozygosity to be increased.

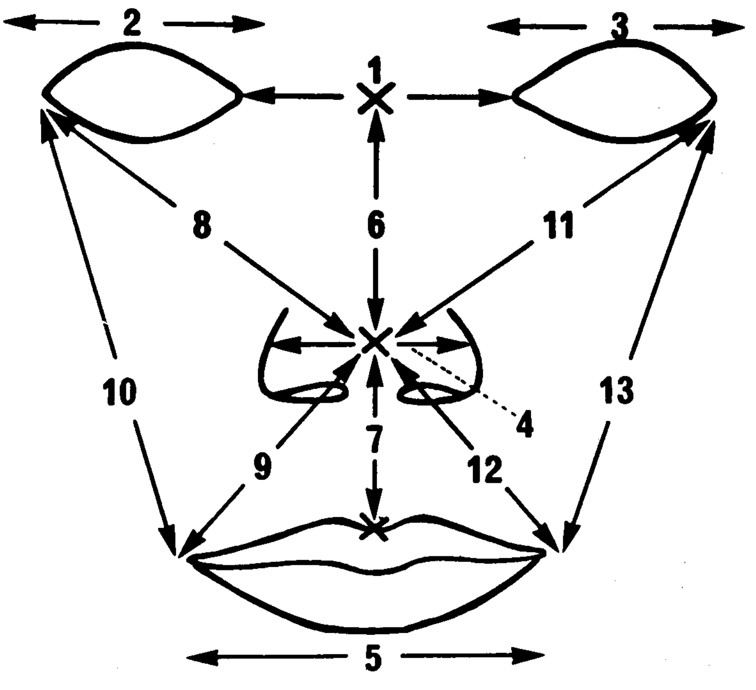

Fig. 2. Selection of facial parameters based on soft tissue landmarks.

A total of 274 facial maps provided over 3,500 measurements of facial parameters. Each parameter was measured on the map using an x,y digitisor [8], feeding the contour heights of the landmarks into the computer. All parameters were three-dimensional. Of the selection used in the original study, it was found that parameters 1, 2 and 3, concerned with the eyes (Fig. 2), followed a "neural" pattern of growth as originally described by Scammon [18], whereas parameters 4 to 13 followed a different growth pattern which included an adolescent growth spurt [7,9].

Each measurement was age-corrected to the nearest whole year using the transformation figures on growth charts [21]. Each map records the face life-size in contour lines, with a contour interval of 2 mm (Fig.1). The outlines of the eyes, nares and mouth are correctly related to the countour lines. Nose tip is given zero value and is defined as the centre of a circle of 4 mm diameter, resting on the summit plateau of the nose tip. Anatomical soft tissue landmarks are used to define the other parameters which were selected to be nonoverlapping (Fig.2).

Each series was then three-point smoothed, ie, each reading was replaced by the mean of itself, the preceding and subsequent readings, thus losing the first and last reading of any series. This procedure reduces measuring error and is valid, providing errors are random. One member of MZ pair no. 2 suffered from a cleft of the lip, and the two parameters concerned with the mouth (parameters 5 and 7, see Fig. 2) were excluded from the series. In isolated observations, the subject blinked at the time of photography and the parameters measuring eye width (parameters 2 and 3) were also excluded. There remained some 2,300 readings providing over 1,150 intrapair differences for analysis.

Table 1 - Various characteristics for twin pairs related to their zygosity

Twin pair no.[a]	Zygosity diagnosis based on hematology[b]	Fingerprint ridge count	Standing height (mm)	Mean & SD intrapair tooth size (mm)	Hair colour[c]	Eye colour[c]	Zygosity diagnosis[d]
11	DZ	154/79	1713/1787	0.186 ± 0.165	C	C	DZ
18	DZ	52/54	1689/1565	0.265 ± 0.235	D	C	DZ
21	DZ	102/151	1635/1638	0.292 ± 0.258	D	C	DZ
5	–	130/98	1610/1619	0.364 ± 0.322	D	D	(DZ)
12	DZ	186/136	1746/1672	0.785 ± 0.696	C	C	DZ
7	DZ	134/112	1626/1549	0.182 ± 0.223	C	C	(DZ)
23	DZ	148/75	1587/1581	0.150 ± 0.133	D	D	DZ
16	DZ	131/68	1811/1692	0.252 ± 0.161	D	D	DZ
25	MZ (93%)	83/66	1607/1619	0.124 ± 0.109	C	C	MZ
3	MZ (88%)	164/172	1737/1742	0.060 ± 0.053	C	C	MZ
19	MZ (99%)	160/144	1711/1597	0.327 ± 0.290	C	C	MZ
27	–	139/131	1632/1616	0.113 ± 0.100	C	C	(MZ)
1	MZ (96%)	156/145	1785/1792	0.062 ± 0.055	C	C	MZ
26	–	181/176	1571/1559	0.092 ± 0.082	C	C	(MZ)
20	–	85/79	1679/1657	0.092 ± 0.081	C	C	(MZ)
2	MZ (92%)	36/56	1616/1618	0.105 ± 0.093	C	C	MZ
9	MZ (94%)	89/79	1707/1704	0.171 ± 0.152	C	C	MZ
17	–	87/67	1562/1562	0.153 ± 0.135	C	C	(MZ)

[a] Numbers 1-13, male pairs; 14-27, female pairs.
[b] Probability of monozygosity given as percentage in parenthesis.
[c] C = concordant; D = discordant.
[d] In brackets without hematology.

Since the parameters varied considerably in size, it was decided to relate the mean intrapair difference for each series of observations as a percentage of the mean of the two parameters being compared. Thus, proportional intrapair differences for each parameter could be compared. The means and standard deviations of all 13 parameters for each twin pair series could also be calculated for each twin pair. These evaluations provided a facial index of "facial similarity or dissimilarity". The twin pairs were then arranged in order of magnitude of the index and related to the table of zygosity diagnosis (Table 1) based on characteristics other than facial.

The sample favoured the MZ group, mainly in length of observation, but slightly in numbers of twin pairs also. This was designed to produce more reliable mean percentage intrapair differences from a larger number of annual observations, since it was presumed that they would be smaller, hence more difficult to measure with sufficient accuracy.

Accuracy of Method

The original analysis of variance [5] was based on the same face being photographed on three separate occasions and two plots being constructed from each stereo pair. At that time, the variance was expressed as the standard deviation of repeated measurements on 6 sets of 13 linear facial parameters, which was found to be 0.69 mm, of which most (0.65 mm) was due to plotting error. If this variance is expressed in terms of x, y, z coordinates, the standard deviations are $x = 0.177$ mm, $y = 0.242$ mm and $z = 0.279$ mm. The coordinate variance includes the posing error, whereas the linear parameters do not [6].

RESULTS

Table 1 refers to the hematological findings and certain physical characteristics for the twin pairs. Each twin pair of the original sample was numbered: 1-13 being boys and 14-27 girls. The present group of 18 pairs was selected from the larger group on grounds of continuity of observation and balance of zygosity. Of the 36 children, blood tests were available for 26 and, of these, 2 MZ pairs had parents who were also tested. The zygosity of the remaining 5 pairs was judged by fingerprint ridge counts, standing heights at the oldest observed age, tooth size intrapair differences derived from Katwan's data [14], and hair and eye colour. Where no serological tests were available, the final diagnosis of dizygosity or monozygosity was given in brackets in the last column, which also listed the serological diagnoses, with percentage probabilities of monozygosity given in the second column.

Tables 2 and 3 list the mean percentage intrapair differences for facial parameters 1 to 13 for the MZ and DZ twin pairs, respectively. Levels of significance are given in Table 3. In each table, the first column indicates the twin pair number and, in the second column the number of years for which the twin pair was under annual observation. At the end of the data for each twin pair, a mean and standard deviation has been calculated for all 13 parameters. Below the percentage column for each parameter, a mean intrapair difference and standard deviation is listed. Finally, means and standard deviations were calculated to compare all MZ and DZ intrapair differences. These groups proved to be significantly different, ($t = 2.79$, $P < 0.02$ for 16 df).

Table 2 - Mean percentage intrapair differences of 13 facial parameters in 10 MZ twin pairs

Twin pair no.	Obs. period (yr)	Parameter 1	2	3	4	5	6	7	8	9	10	11	12	13	Mean (%)	SD (%)
1	5	3.15	1.41	2.10	3.87	0.84	3.40	2.36	1.13	2.22	0.46	0.79	1.17	2.75	1.97	1.09
2	10	4.44	2.90	2.50	2.10	–	4.10	–	0.86	3.60	1.27	1.17	3.63	1.61	2.59	1.30
3	9	3.69	1.94	5.82	2.12	2.02	3.98	2.89	3.05	1.38	0.18	4.07	2.45	2.11	2.75	1.42
9	8	1.15	1.44	1.56	1.67	3.06	2.68	2.47	3.12	3.19	3.41	2.33	1.46	2.12	2.28	0.77
17	9	2.36	2.11	3.26	2.28	1.70	1.64	1.81	2.48	0.94	1.39	1.67	1.13	2.25	1.92	0.62
19	8	3.76	2.07	3.11	6.33	4.53	2.12	4.79	1.69	4.26	1.56	3.19	3.90	4.63	3.53	1.42
20	10	3.32	2.69	1.38	2.32	2.90	5.87	4.55	4.22	2.35	1.67	1.91	1.67	1.35	2.78	1.37
25	8	0.81	2.82	2.69	2.42	3.75	1.19	3.12	1.42	2.60	1.22	2.74	3.79	2.22	2.36	0.96
26	9	3.26	1.16	3.19	1.74	4.54	1.86	3.10	3.22	1.43	1.81	3.15	4.07	2.22	2.67	1.04
27	7	3.27	5.31	1.67	2.11	4.02	2.62	2.58	3.17	2.61	1.97	3.67	1.52	2.61	2.86	1.04
Mean		2.92	2.68	2.73	2.69	3.04	2.98	3.07	2.44	2.46	1.49	2.47	2.48	2.39	2.57	1.10
SD		1.15	1.42	1.29	1.41	1.31	1.44	0.99	1.10	1.04	0.88	1.08	1.24	0.89		

Table 3 - Mean percentage intrapair differences of 13 facial parameters in 8 DZ twin pairs

Twin pair no.	Obs. period (yr)	Parameter 1	2	3	4	5	6	7	8	9	10	11	12	13	Mean (%)	SD (%)
5	6	7.63	14.42	18.16	11.05	3.91	6.86	6.81	10.80	3.66	2.23	9.59	3.54	2.42	7.78	4.88
7	10	11.34	5.02	5.99	5.25	2.50	3.85	3.05	2.20	1.99	4.45	1.86	2.13	1.94	3.97	2.64
11	5	15.80	14.62	8.72	9.88	14.0	14.67	2.29	10.00	4.36	4.87	2.92	2.62	2.79	8.27	5.24
12	5	14.05	1.80	3.26	5.30	14.76	7.82	4.46	1.73	9.95	5.17	3.48	7.40	6.12	6.56	4.20
16	6	9.46	4.72	2.86	2.64	3.85	3.80	11.63	2.62	4.51	1.59	2.95	2.54	3.13	4.33	2.92
18	4	12.24	14.52	4.79	2.04	6.39	11.99	5.37	9.24	7.95	4.68	7.86	3.23	0.52	6.99	4.18
21	4	3.70	4.57	1.92	9.40	9.29	16.46	13.23	10.35	2.99	10.47	2.65	5.38	5.37	7.37	4.51
23	5	20.36	4.64	1.82	3.71	2.52	7.58	14.88	5.31	2.60	3.83	4.00	14.57	2.22	6.77	5.95
Mean (%)		11.82	8.04	5.94	6.16	7.15	9.13	7.71	6.53	4.75	4.66	4.41	5.18	3.06	6.50	4.31
SD (%)		5.12	5.46	5.45	3.49	4.99	4.78	4.86	3.98	2.78	2.68	2.77	4.18	1.84		
t value, 16 df		2.66	2.91	1.81	2.63	2.40	3.49	2.97	3.12	2.07	3.53	2.04	1.95	1.01	2.79	
Significance level		*	*	ns	*	*	**	**	**	ns	*	ns	ns	ns	*	

* Significantly different at 0.05 level.
** Significantly different at 0.01 level.

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The individual mean intrapair differences and standard deviations range from 1.92% ± 0.62% to 3.53% ± 1.42% for MZ group, and from 3.97% ± 2.64% to 8.27% ± 5.24% in the DZ group, indicating some degree of overlap between the groups. In an effort to improve the differentiation, the individual parameters were examined for statistically significant differences and the following parameters were found to differ at levels of 0.05 or higher (Table 3): Intercanthal width (parameter 1); Right-eye width (parameter 2); Nose width (parameter 4); Mouth width (parameter 5); Nose height (parameter 6); Upper lip height (parameter 7); Distance from right external canthus to nose tip (parameter 8); Distance from right external canthus to right angle of mouth (parameter 10).

Table 4 - Facial indices based on 7 parameters in order of decreasing magnitude showing separate distribution of MZ and DZ twin pairs

Twin pair no.	Mean (%)	SD (%)	Diagnosis[a]
11	11.43	4.82	DZ pairs
5	9.83	5.00	
21	8.37	5.30	
18	8.19	4.68	
23	7.93	7.05	
12	7.35	5.17	
16	5.57	3.53	
7	5.29	2.95	
19	3.82	1.54	MZ pairs
20	3.29	1.49	
2	3.27	1.09	
3	3.21	1.41	
27	3.08	1.24	
26	2.69	1.16	
1	2.45	1.10	
25	2.40	1.05	
17	2.17	0.56	
9	2.00	0.72	

[a] Cf. Table 1.

The means for other parameters were smaller in the MZ differences, but not significantly so. Since the main group of parameters which did not differ significantly were oblique, ie, parameters 9, 11, 12 and 13, it was decided to omit all oblique parameters and use a new facial similarity index based on parameters 1 to 7 only, all of which measure vertical or horizontal features of the face. Of this group, all differed significantly, apart from parameter 3. The values for the new facial index, based on seven parameters only, are listed in order of decreasing magnitude in Table 4.

The MZ and DZ groups are now more clearly differentiated. The t values for the facial indices groups were found to be statistically different at a higher level of significance than was found for the index based on all 13 parameters: $t = 3.31$ with 16 degrees of freedom is significantly better at 0.01 level.

The range for facial indices for the MZ twin pairs was 2.0% to 3.82% and for the DZ pairs it was 5.29% to 11.43%. Thus, the differentiation of the two groups is improved, giving better guidance for zygosity diagnosis. It appears, therefore, that a more sensitive index for facial similarity may be based on intrapair differences in simple three-dimensional facial parameters measuring:

1) the width of the palpebral fissures and the distance by which they are separated;
2) the alar width and dorsal height of the nose;
3) the width of the mouth and the distance by which it is separated from tip of nose.

It is essential that all seven parameters be measured as isolated large, intrapair percentage differences occur in the MZ twin pairs (Table 2) and similar isolated small differences occur in the DZ twin pairs (Table 3).

DISCUSSION

Galton [12] first drew attentin to the oppurtunity of studying the relative effects of nature and nurture on man by studying twins. The crux of the problem lies in the reliability of the diagnosis of zygosity, as already stressed, among others, by Stern [20].

For these reasons, the diagnosis of zygosity in this study has been firmly based on hematological reports whenever possible. When not available, a combination of other physical traits, already investigated in twins, have been used: standing height [17], fingerprint count [19], tooth size [16 and 14], and hair and eye colour [17].

Figure 3 shows the facial features for one MZ (above) and one DZ (below)twin pair. The facial similarity between the MZ twins (mean intrapair facial difference 2.45% ± 1.10%) and the dissimilarity between the DZ twins (mean difference 8.37 ± 5.30%) is evident visually and in the figures.

The diagnosis of zygosity based on physical traits in this group agrees in general with the hematological reports. However, there are two twin pairs whose phenotypic intrapair differences do not correspond. In both pairs the hematology report would be accepted as reliable. In twin pair no. 19 the probability of monozygosity was 99%, yet there were large differences in fingerprint ridge count and standing height. Hair and eye colour matched. The other pair (no. 7) was diagnosed hematologically as DZ, but showed relatively small differences in facial parameters, standing height and tooth size. Hair and eye colour matched. Thus, as with many other physical characteristics, facial parameter size difference range overlaps between MZ and DZ twin pairs. In this situation, this trait can only be used to indicate probability based on the distribution of mean intrapair difference of seven facial parameters, as described above.

It seems, therefore, that the widely accepted generality that stereoscopic vision records similar faces in MZ, and dissimilar faces in DZ twins, has a real basis which can be measured three-dimensionally.

a)

b)

Fig. 3. Examples of facial photographs of:
(a) MZ twin pair no. 1 (above); (b) DZ twin pair no. 21 (below).

However, the modified facial index based on seven parameters was able to place both of these twin pairs in their correct group, according to their hematology, and completely segregated the groups in terms of means (Table 4). A Student t test showed that the two groups were significantly different at the 0.01-0.001 level.

Wilson [24] discussed large differences in height and weight in young MZ twin pairs. He explained, quoting Falkner [11], that such differences may arise prenatally due to an arteriovenous shunt anastomosing in monochorionic placentae resulting

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in a deprivation of blood supply to one fetus. He also speculated that "buffering", which normally protects the child or the fetus from environmental insult, may be weaker in the smaller twin. In his large group of 900 twins, there were 10 MZ pairs with one twin severely underweight at birth. Of these 10 pairs, 4 still had differences in standing height of 4 cm or more at the age of 6 years. The zygosity diagnosis was based on 22 red cell antigens. Thus, it is possible to get large intrapair differences in MZ twin pairs.

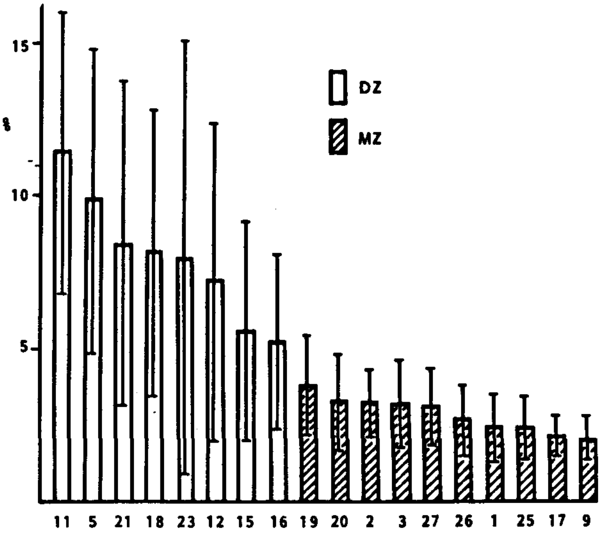

Fig. 4. Histograms of mean percentage intrapair difference for each twin pair, with standard deviations.

In a large investigation in 646 older twins, Ljung et al [15] based their twin diagnoses on the inspection of the face, especially teeth, ear and nose shape, frontal hairline and hair and eye colour. They subsequently checked the diagnosis for 71 twin pairs using a group of 22 blood antigens and found their diagnoses to be correct in 68 pairs out of 71. Three pairs who were originally diagnosed as being MZ were in fact serologically DZ. Twin pair no. 16 in this study presented a similar combination of small intrapair differences, although serologically DZ. Conversely, twin pair no. 19, serologically MZ with 99% probability, presented quite large facial differences and these possibilities should be borne in mind in any twin study using facial inspection to diagnose zygosity.

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Correspondence: Prof. Peter H. Burke, Department of Child Dental Health, University of Sheffield, Wellesley Road, Sheffield S10 2SZ, UK.