

Changes in eye colour during early childhood: sex and genetic differences

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Summary. Eye colour was assessed routinely from 3 months to 6 years for children participating in a longitudinal study of twins. There were 169 female twin pairs, 161 male pairs, and 60 opposite-sex pairs. Age trends, established by sampling only one member of every pair, showed a marked decrease in lighter colours and a corresponding increase in darker colours with age. The eye colour of females was more represented by darker shades, and was more likely to be changing rather than remaining stable with age. Within-pair concordance rates were calculated for same-sex pairs whose zygosity had been determined independently through bloodtyping. A high rate of concordance was found for MZ twins at every age in spite of the general change toward darker colours with age, indicating a strong genetic influence in the timing of eye colour changes. In contrast, the rate of concordance for DZ twins decreased regularly so that, by 6 years, only about 50 per cent of fraternal pairs were concordant for eye colour. Results are discussed in terms of accelerated maturation of females, and the need for genetic models of the inheritance of eye colour which are both age- and sex-specific.

1. Introduction

Studies of eye colour have typically found that the adults of North European origin have more darkly pigmented eyes than the children of the same populations (Bean, 1935; Brues, 1946; Keogh and Read, 1963; Rufer, Bauer and Soukup, 1970). The assertion has therefore been made that eyes become darker from birth to maturity, the period of greatest change usually being considered to be adolescence (Scheinfeld, 1965). There are no data available, however, which demonstrate stability or instability of eye colour in earlier childhood.

In the Louisville Twin Study, eye colour has been routinely assessed in a longitudinal study of twin children. This paper reports upon the distribution of eye colours, sex differences, probabilities for change in eye colour, and genetic influences in the timing of change during the first six years.

2. Materials and methods

Twins participating in the Louisville Twin Study have been recruited over the past decade from families who reside in the metropolitan area of Louisville,

Kentucky. About 80% of the community is of European origin, predominantly composed of Northern European, English, Scottish, and Irish descendants. Only twins of this origin are included in this report. A more detailed description of the sample can be found in Vandenberg, Stafford and Brown (1968), or Wilson, Brown and Matheny (1971).

The sample includes 169 female pairs, 161 male pairs, and 60 opposite-sex pairs. Zygosity determination was based on concordance or nonconcordance on 22 or more blood-group factors (Race and Sanger, 1968; Wilson, 1970). Discrepancy on any of the antiserum tests classified the pair as fraternal. Since zygosity determination is not made until the twins are three years of age, this sample includes some untyped same-sex pairs.

The London Eye Colour Scale was used to match the children's eye colour at each designated age (± 2 weeks). The 15 colours of the scale were grouped into three major categories: colours 1 to 5 (blues) are referred to as *Light*, 6 to 10 as *Medium*, and 11 to 15 (browns) as *Dark*.

For analyses dealing with distributions of eye colours by age and sex, data from *only one member of each twin pair* (randomly selected) were used; for genetic analyses, the sample included both members of same-sex pairs for whom zygosity had been determined by bloodtyping.

3. Results

Age and sex differences

To obtain the best estimate of the distribution of eye colours, one member of all available pairs at each age was sampled, regardless of how long the twin pair had been in the study. The findings in table 1 therefore are based on mixed cross-sectional and longitudinal data. The trend for both sexes is clearly toward higher percentages of darker eyes with increasing age. However, a sex difference is apparent with males more represented in the light, and females in the dark categories. By 6 years of age, over one-half of the females, compared to about one-third of the males, are found in the dark category. A series of χ^2 tests made for the differences in eye colour between female and male children indicated that the sex difference is significant at 4, 5 and 6 years.

Age (months)	Female				Male			
	Light	Medium	Dark	N	Light	Medium	Dark	N
3	75	15	10	102	82	9	9	112
6	62	20	18	119	75	13	12	118
9	57	19	24	116	67	19	14	106
12	53	21	26	124*	68	15	17	114*
18	44	24	32	135*	58	21	21	120*
24	42	22	36	142	50	24	26	127
36	37	25	38	126	43	31	26	127
48	31	25	44	103**	34	38	28	104**
60	29	24	47	110**	35	35	30	106**
72	26	23	51	98**	32	38	30	93**

Sex differences were tested by Contingency χ^2 . * $P < 0.10$; ** $P < 0.05$.

Table 1. Percentage of light, medium and dark categories of eye colour for female and male children.

In order to calculate the probability of eye colour changing rather than remaining stable from age to age, the sample was reduced to those children whose eye colour had been consistently assessed during the first six years. Again using only one child from any pair, this selected cohort resulted in a true longitudinal sample of 44 males and 43 females. A preliminary analysis indicated that, at any age, the distributions of eye colours for this selected sample did not differ significantly from the total sample distributions presented in table 1. Table 2 shows the percentages of children with eye colour remaining stable or changing from each age to the next, by colour category and sex. Taken collectively, the percentages illustrate a generalized tendency toward darkening of eye colour in the first six years for this longitudinal sample. The relative excess of dark eyes among females and light eyes among males is particularly obvious.

Age in months at successive assessments	Stable						Colour changing	
	Light		Middle		Dark		Female	Male
	Female	Male	Female	Male	Female	Male		
3 and 6	52	83	14	8	19	4	15	4
6 and 9	47	68	9	13	24	10	21	9
9 and 12	42	67	15	14	25	14	16	6
12 and 18*	30	56	19	16	28	14	22	14
18 and 24*	27	53	17	17	34	17	21	12
24 and 36**	22	49	22	20	41	24	15	7
36 and 48**	18	44	20	19	45	26	16	12
48 and 60**	14	40	23	21	52	33	11	7
60 and 72*	14	37	25	21	52	33	9	9

Sex differences were tested by Contingency χ^2 . * $P < 0.10$; ** $P < 0.05$.

Table 2. Percentage of female and male children with eye colour remaining stable or changing between successive assessments.

A further series of χ^2 tests were made for the differences in eye colour between the females and males in the longitudinal sample. After the first year, each subsequent period tended to show sex differences. The females tended to be more represented by dark shades, less represented by light shades, and more subject to change. Thus, the longitudinal data suggest that the major trend is for children's eyes to darken with age, a change which is accelerated among females.

Genetic analysis

The same-sex twin pairs were reconstituted with between 50 and 60 pairs for each of the following groups: identical female, identical male, fraternal female, and fraternal male. At any given age, eye colour data were generally available for more than half of the total sample.

The degree of similarity for eye colour was determined by finding the frequency of pairs with both twins in the same colour category. No sex differences were found for within-pair concordance; therefore, for this analysis the sexes were combined, and only the differences between identical and fraternal twins are reported. The figure presents the concordance rates, in percentages, for identical and

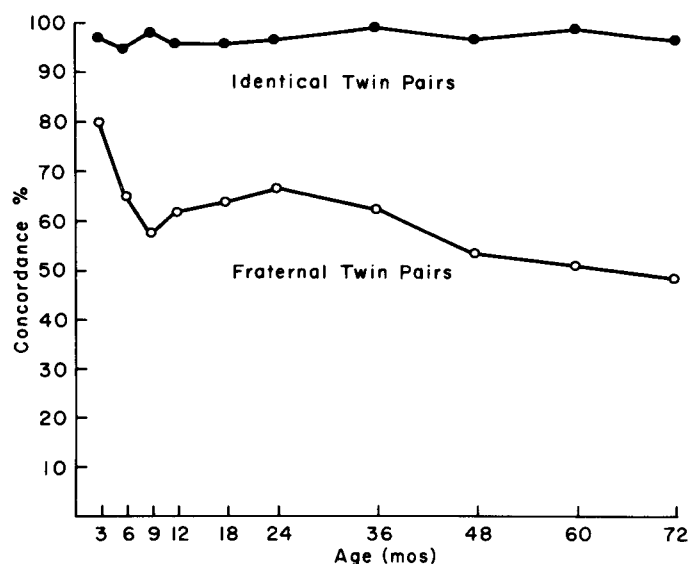


Figure. Concordance rates for the eye colour of identical and fraternal twins.

fraternal twins. Considering that there are eye colour changes in childhood, the high rate of concordance for the identical twins at any given age suggests a strong genetic influence in the timing of the changes. By way of contrast, the fraternal twins' concordance rate is high initially, but gradually decreases so that, by six years, only about 50% of the fraternal pairs are concordant for eye colour. The differences in concordance for identical and fraternal twins were significant at every age.

4. Discussion

The results from this study indicate that changes in eye colour during the pre-school years are to be expected among children of North European origin. Such changes are unidirectional, exemplified by the consistent increase in the frequencies of dark colours and the corresponding decrease in the frequencies of light colours. The change is accelerated for female children, and in view of the reported significant excess of dark-eyed adult females, evidently reflects a true sex difference. Apparently, among individuals whose eye colour will change, the maturational target is darker eyes. Females reach the target earlier than males, in a manner analogous to other patterns of physical maturation for males and females.

These results are not in agreement with those of Babickova and Halkova (1970), who found no changes in eye colour for children between 4 and 9 years in their Czechoslovakian sample. In our data the greatest changes occurred prior to 4 years; while there was a reduction in rate of change after 4 years, some shifting was still occurring at least to 6 years. These results, therefore, raise questions about the utility of testing hypotheses on the heredity of eye colour without taking into account age and sex. Rufer *et al.* (1970), for example, evaluated the eye colour of young children (aged 24–30 months), and their mothers by means of the Martin–Schultz eye colour scale. Their data indicated that the mother–child relationship for eye colour supported Davenport's hypothesis regarding the

heredity of eye colour. If, in their population of children, as in ours, change in eye colour occurred after 30 months, one would find it difficult to support a simple genetic model for eye colour. Further, if the rate of change of eye colour past 30 months is different for females and males, then the genetic model would have to be sex-specific as well as age-specific. These factors should also be considered before applying genetic models to the resolution of medical-legal questions, such as establishing paternity, or placing children for adoption.

To our knowledge, genetic models for the inheritance of eye colour have not taken into account developmental trends. One could speculate that children whose eye colour changes over time, represent different genotypic influences than those whose eye colour remains consistently in one range. In this sense, the instability of eye colour with age is as genetically determined as the terminal colour itself. Such a genetic model, of course, would have to be derived from populations for whom longitudinal data on eye colour were available for both parents and children.

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Zusammenfassung. Augenfarbe wurde routinemässig geschätzt von 3 Monaten bis 6 Jahren an Kindern, die an einer Längen-Studie für Zwillinge teilnahmen. Da waren 169 weibliche Zwillingspaare, 161 männliche Paare und 60 männliche-weibliche Paare. Alter-Neigungen zeigten, festgestellt durch Muster von einem Mitglied nur von jedem Paar, eine bemerkenswerte Verringerung in hellen Farben und eine entsprechende Vermehrung von dunkleren Farben mit Alter. Die Augenfarbe von weiblichen war mehr vertreten mit dunkleren Nuancen und wechselten viel eher als dass sie im Alter stabil wären. Uebereinstimmungszahlen innerhalb des Zwillingpaares wurden berechnet für Gleich-Sex Paare deren Zygotität wurde unabhängig durch Bluttypen bestimmt. Eine hohe Rate von Uebereinstimmung wurde für MZ-Zwillinge gefunden in jedem Alter trotz dem allgemeinen Wechsel zu dunkleren Farben mit dem Alter, anzeigend einen starken genetischen Einfluss auf die Zeiten des Augenfarbe wechsel. Im Gegensatz, die Uebereinstimmungsrate der DZ-Zwillinge nahm ordentlich ab, sodass im

Alter von 6 Jahren, nur ungefähr 50% von brüderlichen Paaren stimmten in der Augenfarbe überein. Resultate werden diskutiert in Betracht von beschleunigter Reife wurde; 54 wurden sexweise korrekt erkannt mit einer Wahrscheinlichkeit von mehr als 0,95. Es ist jedoch anzunehmen, dass die Genauigkeit die hier erzielt wurde, würde nicht erreicht bei Anwendung der Information dieser Referenzgruppe an neuem Material.

Résumé. La couleur des yeux a été mesurée régulièrement de 3 mois à 6 ans chez des enfants faisant partie d'une étude longitudinale de jumeaux. Cet échantillon comprend 169 paires de filles, 161 paires de garçons, et 60 paires de sexes différents. L'évolution avec l'âge, observée sur un des membres de chaque paire, va dans le sens d'une diminution des couleurs claires et d'une augmentation des couleurs foncées. La couleur des yeux avait tendance à être plus souvent foncée chez les filles, et à changer plutôt que de rester stable. Les taux de concordance à l'intérieur des paires ont été calculés pour les paires de sexe identique dont on avait déterminé s'ils étaient homozygotes ou non d'après les types sanguins. Un taux élevé de concordance a été trouvé chez les jumeaux MZ à chaque âge malgré la tendance générale à évoluer vers une teinte plus foncée, ce qui indique une forte influence génétique sur la chronologie de cette évolution. Au contraire, chez les jumeaux DZ le taux de concordance diminue régulièrement et on trouve une concordance pour seulement 50 pour cent des paires à 6 ans.

Les résultats sont discutés en se référant à la maturation plus rapide des filles, et ils démontrent le besoin de modèles génétiques de l'hérédité de la couleur des yeux qui soient spécifiques pour l'âge et le sexe.