Errors of judgement at Greenwich in 1796

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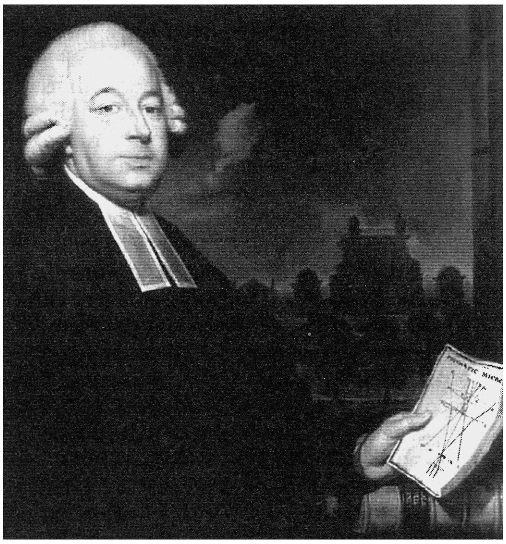
The origins of experimental psychology can be traced back to 1796, when the then Astronomer Royal dismissed his assistant for making some seemingly inaccurate measurements. But there is more to the story than meets the eye.

THIS year marks a bicentenary significant for both astronomy and cognitive science. In the winter of 1796, the 63-year-old Astronomer Royal, Nevil Maskelyne, dismissed his 24-year-old assistant, David Kinnebrook, on the grounds that Kinnebrook differed from him by 800 milliseconds in judging stellar transits — that is, in estimating the moment a given star passed the meridian wire in the Greenwich telescope. The incident, recorded in the printed version of the Greenwich observations[1] and noted by von Lindeneau in 1816 (ref. 2), prompted Bessel at Königsberg to study differences between himself and other well-practised observers[3]. Bessel introduced to astronomy the concept of the 'personal equation', an attempt to correct for the constant errors of particular observers, and his measurements led to the general realization that perceptual and cognitive processes took a quantifiable time. This astronomical interest in the personal equation in turn gave rise to the studies of reaction times and order judgements that dominated the first laboratory of experimental psychology, founded by Wundt in Leipzig in 1879 (refs 4–6); and chronographic instruments, developed by astronomers to minimize personal differences, provided the necessary apparatus[7,8]. Historians have taken Kinnebrook's dismissal to be the event that gave birth to experimental psychology[9,10]. Drawing on previously unknown correspondence and a new analysis of the raw data, we here re-examine the events around 1796.

Transit observations at Greenwich in 1796 were made with a telescope of eight-foot focal length constructed by John Bird of London, installed in 1750 and mounted between masonry piers with the optical axis in the north–south meridian. In the image plane of the telescope were mounted five vertical wires, the central wire corresponding to the meridian. Judgements were made by the well-tried 'eye-and-ear' method of Maskelyne's predecessor, James Bradley[1,11]. As the star (or other object) approached each wire, the observer noted the position of the second-hand of the transit clock (which had a one-second beat). He then began counting the beats, and noted the distance of the star from the wire on the beat before the transit and its distance from the wire on the beat after the transit. He then mentally translated the ratio of the two spatial intervals into a temporal ratio, so estimating the moment of transit. He then prepared for the next wire, adjusting laterally the ocular of the telescope so that it was optically centred on the wire currently being used. The right ascension of the star was estimated by reducing the five separate readings to give an average time for the passage of the central meridian wire. The interval between the readings



Fifth Astronomer Royal: Nevil Maskelyne (1732–1811).

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depended on the declination of the star but (in the data we analysed) had a mean of 39.5 seconds. We estimate that the spatial interval travelled between two clock beats was always less than 20 minutes of visual angle (so spatial error is possible).

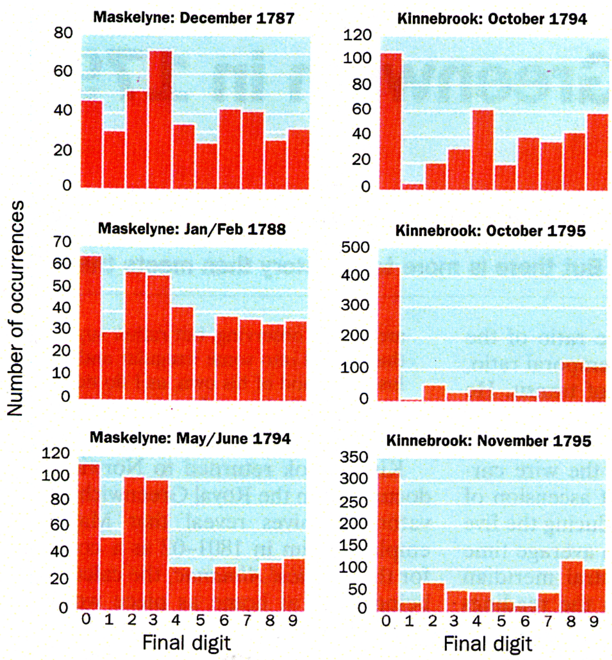
Maskelyne believed that the right ascension could be estimated with a precision of the order of 100 msec. Kinnebrook's 'error' of 800 msec was serious. For on the transit judgements depended the running of the Greenwich clock. On the clock depended estimates of longitude. And on longitude depended the British Empire. Maskelyne wrote[1]:

> As he had unfortunately continued a considerable time in this error before I noticed it, and did not seem to me likely ever to get over it and return to a right method of observing, therefore, though with reluctance, as he was a diligent and useful assistant to me in other respects, I parted with him.... I cannot persuade myself that my late assistant continued in the use of this [Bradley's] excellent method of observing, but rather suppose that he fell into some irregular and confused method of his own, as I do not see how he could have otherwise committed such gross errors.

Kinnebrook returned to Norwich, and documents in the Royal Greenwich Observatory Archives reveal that Maskelyne employed him in 1801–02 as a computer for the *Nautical Almanac*, the calculations being done at home as piece work. He died a bachelor in Norwich in May 1802, still only 30 years old[12,13].

In the literature of experimental psychology, the discrepancy between the estimates of Maskelyne and Kinnebrook is often attributed to 'prior entry', a phenomenon of selective attention: an event arriving on a channel to which we are attending is perceived as earlier than a concurrent event arriving on a channel to which we are not attending[14]. Modern experiments confirm the existence of prior entry for discrete events, but the subjective displacements are of the order of 50–100 msec (ref. 15). An alternative view, traceable to Bessel himself[3], is that time is lost in the switching of attention from one channel to the other: the observer who attends primarily to the clock will switch his attention at the critical beat and will find the star at a more advanced position than it was at the true instant of the beat. A switch of attention may take around 300 msec (ref. 16). So two observers switching in different directions could partly account for the 800-msec discrepancy between the estimates of Maskelyne and Kinnebrook.

Kinnebrook's dismissal is given a rather different complexion by extant letters he wrote to his schoolmaster father in Norwich and to other relatives, copies of which were secured in 1985 by the Royal Greenwich Observatory. From the start, Kinnebrook's social relationship with Maskelyne was awkward. Soon after Kinnebrook arrived, in May 1794, Maskelyne raised the issue of whether the assistant should dine on his own or with Maskelyne and his family: "I might choose which I pleased", Kinnebrook tells his father, "but finding from the drift of his discourse that it was his wish that I should dine by myself I therefore told him that I could do that which he thought most convenient"[17].



Histograms showing for Maskelyne (left) and Kinnebrook (right) the number of readings in which a particular final digit was used. Both men have marked biases, but in the autumn of 1795 Kinnebrook is rounding many of his observations.

We learn that in October 1794, Kinnebrook broke the fourth perpendicular wire of the transit instrument "either by putting in the compound Eye Glass too far into the tube of the Telescope, or by a slight touch with my Finger"[18]; and in January 1795, during very cold weather, he broke the plumb line of the south mural quadrant[19]. Both events attracted rebukes from Maskelyne, who also disapproved of Kinnebrook's recreational activity, the submission of solutions to mathematical puzzles in the *Ladies' Journal*[20]. When Kinnebrook asked for time off in August 1795, Maskelyne "said it would be very disagreeable to him as the Moon would not transit the mer. till near midnight on Friday and Saturday next and as it is necessary there should be stars observed both before and after the moon's transit, he would be obliged to stay up till between 1 and 2 in the morning"[21]. And in November 1795, while Maskelyne was on his annual visit to Wiltshire (where he enjoyed the income of a living), Kinnebrook entered into a correspondence with Herschel about a new comet observed by the latter. "Dr Maskelyne was much displeased and hinted as if I had kept up a regular correspondence with Dr Hershel. If I had known there had subsisted jealousy between Dr Maskelyne and Dr Hershel I certainly should not have written to Dr Hershel about the Comet"[22].

It is in the same letter, of 17 December 1795, that we first hear of Mrs Wilkinson. "Mrs Wilkinson Dr Shepherd's niece has been at the ob^y about 4 months. She dined with us when my Uncle was at the ob^y. I apprehend there is a scheme planned between Dr M and Dr S to marry Mrs Wilkinson to an assistant." There was but one assistant at the observatory. As pressure was put on him to marry Maskelyne's protegée, Kinnebrook sought his father's advice: "I think it would be best for you to write me upon a thick sheet of paper or else send me a double letter". In a letter of 10 January 1796, Kinnebrook records: "Dr M recommended Mrs… to me as a very prudent woman and urged me very much to have an interview with her on the Tuesday morning". Kinnebrook replied that his father recommended him to continue single[23]. Within a fortnight he was dismissed for having fallen into "a vitious way of observing the times of the Transits too late"[1].

Personal relationships apart, what do the raw data of the manuscript transit book[24] reveal about Kinnebrook's dismissal? Although we do not have an external measure of the absolute accuracy of the observations by Maskelyne and Kinnebrook, clear conclusions can be drawn from the internal structure of the data.

Take the distributions of the final digits used by the two observers. It is known in other contexts (for example, in sphygmomanometry) that operators do not use the digits 0–9 equally when reading dials or scales to a tenth of a division: a given operator will show an unconscious preference for certain digits and this signature may be reasonably stable over time[25,26]. The figure shows for Maskelyne the frequency of use of different digits in two successive periods in 1787–88. (The final digit corresponds to tenths of a second.) The distributions are significantly non-uniform ($\chi^2 = 45.16$; 31.54; $p < 0.001$). The departure from uniformity is not gross, but he has a preference for 0, 2 and 3. By May 1794, just before Kinnebrook starts work, Maskelyne has become more biased ($\chi^2 = 177.8$; $p < 0.001$): he now has a stronger preference for 0, 2 and 3 and is avoiding the larger numbers. A sample of data from Kinnebrook in the autumn of the same year shows a bias ($\chi^2 = 164.7$; $p < 0.001$) different from, and more extreme than, Maskelyne's: he has a strong tendency to round to the nearest second and almost never uses the digit 1. A year later, just before dismissal, he is rounding most entries and seldom gives an estimate to the nearest tenth.

Another way of analysing the data is to consider the standard deviation of the four intervals between the five successive transits used to estimate each right ascension. In May 1794, when Maskelyne was between assistants, the median standard deviation of his readings was 269 msec. The corresponding value for Kinnebrook in his first autumn (October 1794) is 353 msec, and by October 1795 it was 461 msec.

Neither prior entry nor attention switching can fully account for Kinnebrook's error: his judgements are not simply displaced in time relative to those of Maskelyne. Rather, it is as if his perception of the beat migrates in his perceptual memory to coincide with the moment of occultation of the star by the wire. This phenomenon recalls the tendency of a click presented during a spoken sentence to migrate so as to coincide with the break between two clauses[27]. Certainly, Kinnebrook was not a distinguished observer. The pretext for his dismissal was sound, although the real reason for his dismissal may not be the one historically assumed. □

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ACKNOWLEDGEMENTS. We thank D. Dewhirst, D. Jones and L. Morrison for advice.