visible. Individual differences in performance for both target courses were more marked for the no-delay condition and the first three delay values, the standard deviations ranging from 2.8 to 50 seconds. In general, the variability among subjects decreased for both target courses as delay magnitude increased.

These results on the effect of visual transmission delay of one's own pursuit tracking behavior are very similar to those of Warrick (*5*) on compensatory tracking with simulated transmission delay lags of 0 to 320 msec between hand control and a visual indication of the effects of control. Although Warrick's subjects did not have a direct delayed view of their own behavior, and despite the fact that their task was one of compensatory tracking with a complex oscillatory pattern, the relationship found between delay and performance (log time on target) was linear as in the present study, but with a different slope. In tracking behavior, at least, any transmission-type visual delay degrades performance —the larger the delay, the greater the effect—and this conclusion holds for both delay of a visual indicator (such as a pointer) of response and delay of the actual view of one's own response or behavior. In addition, the disturbing effects of delay do not appear to depend on the subject's ability to discern or perceive directly the temporal delay between the operation of a control and its resultant effects, or the delay between his movement and the visual perception of it. While in the present experiment this question was not investigated directly, reports of the subjects indicated that at the three shorter delay values (17, 50, and 80 msec) it was very difficult, if not impossible, to perceive or sense that there was a delay between their hand and arm movements and the visual perception of them. Warrick (*5*) reported similarly for delays of 60 msec or less.

In addition to these effects of delayed visual feedback on performance, a rather striking qualitative or subjective effect is worth noting briefly. When the visual delay is of the order of 250 msec (visual reaction time), one's arm and hand movements take on a peculiar "rubbery" quality in appearance and feel. At longer delays (such as 600 msec) this impression is lost. Whether this proprioceptive-visual interactive effect is transitory will require further study.

The newly developed video disk technology which made the present experiment possible portends important developments in research on visual feedback in relation to organization and control in visual-motor behavior.

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6. I thank T. Hines, W. Jack, and W. Neely for their assistance in this research.

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Patterns in Productivity of Scientists

Abstract. *Bibliographies of 53 eminent research scientists in different fields are analyzed in terms of total publications, type of publication, coauthorship, and mean number of publications per year. For the physical and biological scientists, comparisons are made with the publication records of 153 eminent 19th-century scientists.*

In 1947 I began studies (*1*) of 64 leading American research men in the biological, physical, and social sciences, and I have continued in contact with most of them ever since; this contact included follow-up visits in 1963 (*2, 3*). Last year I was able to get current bibliographies from most of the men. Bibliographies of some who had died were available in the memoirs of the National Academy of Sciences. This report covers publications of 15 biologists, 17 physical scientists (experimental and theoretical) and 21 social

Table 1. Publications of 53 scientists of the 20th century (Exper., experimental; Theor., theoretical; Anthr., anthropologist; and Psychol., psychologists).

Data	Biologists	Physical scientists			Social scientists		
		Exper.	Theor.	Both	Anthr.	Psychol.	Both
			Scientists (No.)				
	15	9	8	17	7	14	21
			Books 1 (No.)				
Mean	2.2	1.2	3.3	2.2	4.1	4.9	4.7
Range	0–8	0–3	0–11	0–11	2–8	0–12	0–12
			Books 2 (No.)				
Mean	2.8	1.3	3.6	2.4	6.0	6.1	6.1
Range	0–10	0–4	1–12	0–12	3–11	1–16	1–16
			Research reports (No.)				
Mean	103.1	95.4	98.2	96.8	25.4	79.9	61.6
Range	38–198	24–199	9–247	9–247	12–50	23–201	12–201
			Other technical publications (No.)				
Mean	31.6	24.7	22.8	23.7	35.6	45.6	42.3
Range	8–66	5–72	2–95	2–95	10–62	17–95	10–95
			Coauthors (%)				
Mean	32	51	35	44	17	40	32
Range	0–86	24–86	0–65	0–86	0–32	9–70	0–70
			Book reviews (No.)				
Mean	8.4	0.8	1.4	1.0	54.6	14.1	27.9
Range	0–35	0–3	0–6	0–6	5–167	0–77	0–167
			Publications per year (No.)				
Mean	3.2	3.4	3.3	3.4	3.4	3.8	3.7
Range	1.1–7.3	1.7–7.4	0.8–8.6	0.8–8.6	1.7–5.4	1.4–6.4	1.4–6.4
			Weighted publications per year				
Mean	3.6	3.7	4.1	3.9	4.1	4.9	4.6
Range	1.1–8.4	1.4–8.2	1.0–10.2	1.0–10.2	2.9–5.3	2.2–9.4	2.2–9.4
			Nontechnical publications (No.)				
Mean	23.5	6.1	4.6*	5.4†	36.7	16.9	23.5
Range	0–79	0–23	0–22	0–23	10–77	2–46	2–77
			Total publications per year (No.)				
Mean	3.6	3.6	2.6*	3.2†	4.2	4.2	4.2
Range	1.4–8.4	1.5–7.5	0.8–4.7	0.8–7.3	2.2–7.1	2.0–6.8	2.0–7.1
			Weighted total publications per year (No.)				
Mean	4.3	3.9	3.4*	3.7†	5.6	5.4	5.4
Range	1.4–12.4	1.5–8.3	1.0–5.4	1.0–8.3	3.1–7.7	2.8–9.8	2.8–9.3

* $N = 7$. † $N = 16$.

scientists (anthropologists and psychologists). These groups are small, but they were selected for eminence, and they are, in fact, a very good representation of eminent men in these fields.

The data are presented in Table 1, but some explanation of terms is needed. Books are separated into new books (books 1) and revisions and edited books (books 2). Translations and successive editions without revision are omitted. Research papers are reports on specific research projects. Other technical publications include such things as surveys, chapters in symposium volumes, and the like. The percentage of publications coauthored is based on the sum of books, research papers, and other technical papers. Book reviews are practically never coauthored, so are not included in those percentages. The denominator for number of publications per year is the time elapsed between the earliest and latest recorded scientific publications, minus (for many of the physicists and some of the others) the years spent on war work, when almost all of their reports were classified. The numerator is the total number of publications: books 1 and 2, research reports, other technical publications, and book reviews.

There is included also a "weighted total per year," which I consider a more accurate measure of productivity than the simple count of publications. This gives different weights to different kinds of publications, with books 1 receiving a weight of 10, books 2 a weight of 5, book reviews a weight of 0.5, and other publications unit weight.

The nontechnical publications also listed in the table include such things as popular articles, encyclopedia articles, discussions of educational problems, biographical memoirs, administrative reports, and the like.

Some kinds of publications are much more common for some scientific groups than for others. Book publication is lowest for experimental physicists, and much higher for all social scientists. Physical scientists tend to publish fewer technical papers, other than research reports, than do the other groups. Discrimination between these categories was difficult, but I have usually been able to get the subject's own judgment. There is also considerable difference in the publication of papers with multiple authors, which is notably rare among anthropologists and, as might be expected, highest among experimental physicists. Perhaps the greatest difference of all among the groups is the extent to which anthropologists publish reviews of other anthropologists' books.

Table 2. Comparisons with scientists of the 19th century (C.); data from Dennis (*4*).

Age	Biological		Physical		Totals	
	Present	19th C.	Present	19th C.	Present	19th C.
			Scientists (No.)			
	15	54	17	99	32	153
			Scientific publications per year (mean and range)			
	3.2 (1.1–7.3)	1.8 (0.2–8.1)	3.4 (0.8–8.6)	2.1 (0.2–16.0)	3.3 (0.8–8.6)	2.0 (0.2–16.0)
			Age at first scientific publication (%)			
15–19	13	0	12	0	13	0
20–24	53	33	65	42	59	39
25–29	33	32	18	33	25	33
30–34	0	17	6	10	3	12
35–39	0	11	0	7	0	8
40–44	0	2	0	4	0	3
45–49	0	4	0	3	0	3
50–54	0	2	0	0	0	1

An analysis of the course of publication over time was made earlier (*2*), and the general results have not changed. The patterns are too varied for categorization and were complicated because of the time devoted to defense activities and the varying ages at which defense work was done. About all that can be said is that the physicists tended to reach the peak of their productivity somewhat earlier than the others; but also, more of them went into administration, which seriously curtails research. Publication of research papers tends to decrease and that of other technical papers to increase with time, but this is far from general. Perhaps the most important thing to note is the persistence in productivity over many years. The men are now 59 to 82 years old; to the best of my knowledge, only three have stopped all scientific work. Two of these are Nobelists. Although many have retired, most still are writing, a few still doing some laboratory work.

Comparisons of the biological and physical scientists of this group with 153 scientists of the 19th century (*4*) are shown in Table 2. The data for the 19th-century scientists are from the *Catalog of Scientific Literature, 1800–1900*, prepared by the Royal Society of London. In some cases, at least, these data would seem to be a considerable underrepresentation of publications (*5*). The lists supplied by Dennis are for 5-year periods, so the number of years used in computing number of publications per year may be up to 4 years too high. Nevertheless it would appear that 20th-century scientists do publish more than 19th-century ones did, and this suggests some major changes in the scientific world.

An even more marked change occurs in the ages at which the first publication appeared, also shown in Table 2. It is much earlier for modern scientists. This also doubtless reflects major changes. For example, all of my subjects had doctorates, and while their thesis work was published in some form, 29 of them had publications antedating this. Scientific training in the 19th century was of a very different sort and, for many of those reported by Dennis, was largely self-acquired. Some of these men, even some of the most eminent, such as Darwin, were by definition amateurs. This accounts in some degree for those who started publishing quite late in life. With respect to major advances in science, it was not too bad a training system, since it automatically eliminated any without extreme dedication.

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4. W. Dennis, *Science* **123**, 724 (1956). Dennis selected from the 1930 edition of *Webster's New International Encyclopedia* each scientist who lived to age 70 or beyond and whose years of life from 20 on fell between 1800 and 1900. He states that in general these men were eminent in their respective fields (fields were not given for three; there were no social scientists), and many are universally famous, even the man with only four publications, the botanist Bonpland.
5. For example, the *Catalog* gives a total of 45 publications for Darwin. By my standards, at least 64 publications in the bibliography by his son should be listed, and the latter figure does not include revisions of books or papers in *Nature* which the *Catalog* might have omitted. See F. Darwin, Ed., *The Life and Letters of Charles Darwin* (Appleton, New York, 1893).

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