Suggestions for an Inquiry into Industrial Fatigue
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SUGGESTIONS FOR AN INQUIRY INTO INDUSTRIAL FATIGUE.

SECTION F of the British Association appointed last year a Committee to inquire into the problem of Industrial Fatigue. The object of this article is to invite co-operation from those who may be in a position to collect data relevant to this question, and to suggest certain directions of research which may prove fruitful.

In respect of many conditions of industrial work we are, or have been until recently, profoundly ignorant as to their real nature and their effects, and this remark is pre-eminently true of the most universal phenomenon in industry—Industrial Fatigue. The existing chaos of legislative regulation of hours of work is hopelessly inconsistent in its inclusion or exclusion of adult males, in its distinctions between mines, textile and non-textile factories, laundries, men's workshops, &c., and in its overtime provisions; but more important than this inconsistency is the fact that the whole of the regulation is purely empirical in its origin, and, moreover, that any scientific judgment as to the suitability of any specific regulation is at the present moment impossible. The truth is that at present we have practically no scientifically ascertained and authentic knowledge as to the nature, causation, and effects of industrial fatigue; for though considerable work has been done on various aspects of fatigue, there has been no attempt to co-ordinate this knowledge and apply it to industry. Yet it is one of the "normal," ever-present factors of industry, and the need for investigation is certainly not growing less with the increasing speed of machinery, the greater demands on intelligence and the consequently increasing nervous strain, the extension of piecework and premium bonus systems, and the development of "scientific management."

The most fundamental question is, of course, what precisely is the connotation of the term "fatigue." This is primarily a question for the physiologist, who as yet has not been able to give a complete answer. Considerable study has been made of

muscular fatigue, and it has been demonstrated that such fatigue arises from the chemical transformation of the glycogen brought by the blood to the muscles into certain fatigue products of which the chief are sarcolactic acid, monopotassium phosphate, and carbon dioxide, and it is believed that the accumulation within the muscle of these substances is the cause of the tired feelings and incapacity to perform further work which we term fatigue. Washing out the muscle with a saline solution removes these substances and restores the efficiency of the muscle, and a similar result ensues in course of time in the normal muscle by the circulation of the blood which removes the fatigue products. But very little is known as to the length of time required for such removal or as to the necessary relation between periods of muscular activity and of quiescence in order to secure equilibrium between generation and removal of the products. However, it is important to notice that "fatigue" has a definite objective origin, and that the individual's consciousness of feelings of "tiredness" are quite unreliable indications of his conditions with respect to fatigue. This has been clearly established by the experimental psychologist, who has also shown definitely—what most of us would suspect to be the case—that continued effort at full capacity results ultimately in less and less output per unit of time, whilst the period required for recovery to normal efficiency rapidly increases. Another of his findings, that, as effort is continued, muscular co-ordination becomes less perfect, will be discussed later, but for the moment its significance lies in its implication that fatigue as it is ordinarily met with, especially in industry—general fatigue—is not fatigue of merely one muscle or even of one set of muscles, each of which is poisoning the blood-stream, but is also connected with the nervous system. But if our knowledge of muscular fatigue is vague and indefinite, that of general fatigue and its relation to the nervous system is infinitely more so. Not only are we ignorant of the nature of the phenomenon, but we are unable to say exactly what is the effect of over-fatigue upon the individual's general physique and power of resistance to certain specific diseases, though the evidence is steadily increasing to show that there is such a connection. Perhaps, from the point of view of the economist, his most urgent requirement from physiologists is the formulation of a standard physiological index of fatigue. The psychologists have, of course, experimented with various tests involving either (1) motor activity (tests of output or of accuracy), or (2) the speed of response to, or accuracy of discrimination of, various stimuli, but there is little general

agreement as to the validity of the tests or their interpretation, and, moreover, it is not necessarily true that when recovery to the normal judged by such tests has been reached that the individual is not still fatigued in the physiological sense. Until, therefore, a reliable physiological index is discovered, it will be impossible to determine scientifically the length of day for the normal worker in any given occupation which results in maximum permissible fatigue, or to investigate fully the fatiguing effects of various occupations and the relative influence of such determinants of fatigue as a high wet-bulb temperature of the atmosphere, speed of operation, muscular *versus* nervous strain, &c.

Meanwhile, whilst he is waiting for the physiologist and experimental psychologist to furnish fuller information respecting the nature and measurement of fatigue, there is a considerable amount of work awaiting the social economist in his own sphere. Although, as has been pointed out, the curve showing variations in the long-period output of work per day, with different lengths of day, cannot be the only determinant of the hours of labour, yet it must always be an important factor. Disregarding for the moment those possible physiological and pathological effects of fatigue which do not affect long-period daily output, it is evident that both employer and worker need for their guidance some knowledge of the way in which output per day varies with the length of day. The efficient employer, if he is working on a one-shift system, desires to secure that length of day which will give him maximum net gain, and in the vast majority of cases this is secured when he obtains maximum output per normal worker per day, *i.e.*, when the length of the working day is the longest possible without in the long run so fatiguing the worker that recovery cannot take place after each day's work, and in consequence the output of the next and succeeding days is reduced. On the other hand, the aim of the worker will not necessarily or even probably be the same; for, as Prof. Chapman has pointed out,[1] a fully-informed worker would desire that length of day where the marginal value of the results of further labour, less the marginal value of the leisure destroyed thereby, equalled the marginal loss due to the disutility of further labour; and it is more than probable that this length of day would be less than that yielding maximum output. Hence there is likely to be continual opposition of interests on this point so long as the one-shift system prevails. The difficulty of applying the reasoning to

[1] Presidential Address to Section F of British Assoc., 1909, reprinted in ECONOMIC JOURNAL.

actual conditions is obvious, however, for even the most objective factor—the long-period curve of output—is unknown. But it is quite possible that at the present time the prevailing length of day in many industries is too long for even maximum output, in which case both employer and worker would gain by a reduction of hours at least to the day of maximum output, and possibly even beyond that. But at this moment there are not adequate data for more than a mere surmise that hours in general are too long; nevertheless, that such a surmise is not entirely devoid of foundation is seen by the four cases cited by Miss Goldmark,[1] where a reduction of hours resulted in the same or an increased output; and it is significant, too, that the literature of "scientific management"[2] shows that in several instances very favourable results have followed a reduction of hours. Other similar instances are given, though with less detail, in Bulletin 118 of the United States Department of Labor and in the Report by the International Association for Labor Regulation on Hours of Labour in Continuous Industries.

The strength of Miss Goldmark's instances is that (i) they are of three industries, *i.e.*, general engineering, small engineering (manufacture of lenses, &c.), and chemical works, the work in which is fairly typical of industrial work generally; (ii) they relate to reduction of lengths of day or hours per week quite commonly found. Hence the results in these cases may presumably be expected in industry generally. The weakness of the instances lies in (i) their small number; (ii) the inadequacy of the data as to the effects on different types of workers—piece and time, young and old, &c.; (ii) the fact that they yield no information as to what would have been the effect of an even greater reduction. It is somewhat astonishing that, despite the research and labour which have evidently gone to the preparation of Miss Goldmark's book, so few cases giving detailed results could be found, and it is in the belief that many more data exist and need but collection and tabulation in order to provide (*a*) more information as to any particular industry; (*b*) a greater variety of instances in different industries, that this appeal for research is issued. Without such information any scientific judgment as to the suitability of hours of labour in any given industry is impossible.

How, then, is the information to be obtained? In, say, the last ten years there have been changes in hours in the case of some individual firms at least in probably most of the staple industries, and it is surely not impossible to obtain access to the information

[1] *Fatigue and Efficiency*, Chap. V. [2] Taylor, *Scientific Management*.

contained in the books of some of these firms. From these records it should be possible to obtain for, say, six or twelve months before and after the change (i) the gross output in units of the commodity per week of certain departments; (ii) the gross number of hours per week worked therein. From these the average output per hour, or the normal output for a complete week at various periods before and after the change could be obtained, and, if care were taken to eliminate cases where there had been any material alteration in machinery or in methods of production, a comparison of such figures in the case of any given firm, checked if possible by those from a similar firm in the same industry, would furnish useful data. A more satisfactory method would be to obtain the hourly output in specified weeks of each of a number of individuals, but it is improbable that the data for obtaining this would be available save in the case of pieceworkers. In such cases a sufficiently accurate index would be the weekly earnings, provided it could be assumed that these represented a full week's work. The advantage of taking individual cases is obvious, for it furnishes information as to the effect of the change on different types of workers—old and young—and also allows of the elimination of cases of learners whose skill is increasing in the period under review. Comparison of the results from departments whose workers are paid by time with others whose workers are all on piecework would give some clue as to the truth or otherwise of the contention sometimes advanced by employers that there would probably be no gain in output proportionate to the reduction in hours amongst time-workers, though in the case of piece-workers such a gain might take place owing to the desire of the pieceworker to attain a certain normal wage. As a matter of fact, the only published instance known to the writer—that of Mather and Platt—shows just the opposite result, *i.e.*, a greater gain in output from time than from piece workers, though the difference diminished towards the end of twelve months after the change. The interpretation would seem to be that the piece-workers were, before the change, more over-fatigued than the time-workers, and took longer to recover from the over-fatigue. It is, however, obviously dangerous to draw any satisfactory inference from merely one case.

Not only could cases of permanent reduction in hours be examined in this way, but much valuable data could also be obtained relating to the effect of short-period alterations—overtime, &c.—from firms in seasonal trades, such as the clothing industry, where there may be two or even more changes in hours

per year. In the case of these trades it would be especially desirable to obtain the figures for selected individuals of normal efficiency, since the proportion of learners is here very high.

The securing of maximum output depends not only upon the length of the working day, but also upon its division into working spells and the inclusion of an adequate allowance of rest intervals. As to what constitutes an adequate allowance, and what should be its distribution over the working period we are even more ignorant than of the right length of day, and it is somewhat astonishing to note that the originator of "scientific management"[1] states that a large number of experiments on workers shovelling pig-iron showed that maximum output was obtained when practically 50 per cent. of the nominal working period was absorbed by short rest intervals. It is perhaps too optimistic to hope that many employers will furnish facilities for experiments comparable to those of Taylor, or even try experiments to test the relative merits of a ten hours' working day worked (*a*) in two spells of five hours, (*b*) in two of five and a quarter hours, with a quarter of an hour rest in each spell; probably, too, the workers would object to the alteration. But although experiment alone can conclusively settle such points, much light might be thrown on the problem if we had some idea as to how the output per hour of the normal worker varies throughout the day—whether it falls, and, if so, in what degree, in the later hours of the spell, and whether recovery occurs after the midday break.[2] There should be little difficulty in obtaining these data in certain types of work where the worker is completing each hour a fairly large number of approximately similar units of work, *e.g.*, in the making of cigarettes, cardboard boxes, small engineering repetition work, moulding of jam-pots, type-setting by hand, packing of sweets, die stamping, &c. Even if individual returns were not obtainable, aggregate returns would afford some information, though, as before, it is desirable to get individual returns in order to note the variations due to age, skill, etc., and especially is it desirable to get individual returns of young persons, since light may then be thrown on the question as to whether the length of spell is markedly too long for such persons, though it may not be for adults. It is further desirable to obtain returns for piece-workers and day-workers in order to see whether the former method of payment results in a tendency to "rush" in the earlier hours,

[1] Taylor, *Scientific Management*.

[2] *Cf.* Investigation by Pieraccini cited by Goldmark.

with consequent exhaustion in the later ones. In cases where a certain task is expected per day, the rush period may occur at the end of the day. Once such returns have been obtained and plotted, it may well be that the employer will be prepared to make the experiment of additional rest intervals at suitable parts of the day—say where the curve begins to drop—and the effect of the interval could then be studied. In like manner the variations in daily output per day of the week and after holidays could be obtained. It is desirable that so far as possible these returns should be obtained without the worker's knowledge in order that ordinary normal conditions should prevail, but if the attempt to do so involves any risk of suspicion or misunderstanding, a frank and tactful explanation should at once be given.

One possible objection should be noted. It may be argued that some falling off in output as the day progresses may be detected in the case of purely manual labour, but that in the case of workers tending machinery the machine determines the output, which is constant therefore throughout the day. This may possibly be true in some cases, but it is certainly not universally true, for in many operations the machine is constantly being stopped for adjustments or for supply of material, and in such cases the output is obviously a function of the length of time consumed in such stoppages, which itself is a function of the worker's fatigue. That subjective factors are important in such cases is evident from the great disparity in wages earned on piecework amongst, say, a group of cotton weavers all working on the same kind of work on looms running the same speed.

So far the suggested investigation has related mainly to output. But there are, as already pointed out, much wider reactions to be taken into account, since the length of day for maximum output may ultimately result in nervous or other physical troubles. The investigation into such matters is, of course, outside the economist's powers, but some information may be gained in the carrying out of the foregoing inquiry in the case of firms which have a sick benefit society or of whose workers a considerable number belong to a local friendly society. But whilst this may not be very conclusive evidence, there is one point—the number and distribution of accidents—on which definite data can easily be secured. It is not intended that the total number of accidents in certain periods before and after a change in hours should be compared, for this may be a function of several objective factors, *e.g.*, improvements in safeguarding machinery, the extent to which floor space is taken up by additional workers or by stocks

of material, the introduction of semi-skilled labour in busy times, &c. The information desired is the percentages of the total number of accidents during, say, twelve months which occur in each hour of the working day for each day of the week, *i.e.*, of those accidents which happened on Tuesdays, the percentage which occurred between 9 a.m.–10 a.m., 10 a.m.–11 a.m., and so on. It has been clearly demonstrated by experiments, some of which have reproduced in some degree the actual conditions of ordinary industrial work, that continued muscular activity results ultimately in faulty muscular co-ordination—in imperfectly controlled movements—which might result in accident in the case of workers such as circular-saw operators, power-press workers, or structural steel erectors, whose work requires them to perform movements with considerable accuracy, at the risk, in case of failure, of personal injury. Very many industrial operations are of this nature, though, of course, in varying degree, and it is believed that the "carelessness" or "inattention" of the worker to which the accident is often ascribed is really a result—wholly or partially—of fatigue; that, as the working spell progresses, there is a growing fatigue, which manifests itself in an increasing imperfection of accuracy of movement or in failure of judgment, and consequently the number of accidents increase in the later hours of the spell. The laboratory experiments of Bogardus[1] showed that in short experimental spells of twenty minutes, where the worker was working at full speed, two-thirds of the total "mistakes" occurred in the latter half of the spell. The published statistics of various American and German Labour Departments[2] also show a marked increase of the percentage of total accidents in the later hours of the spell, the percentage of accidents in the later hours of the morning spell being three or four times that of the first hour, and dropping to an intermediate figure after the midday rest, to rise again later. There are, however, several difficulties in interpreting such statistics:—(1) The figures relate to *all* accidents, and therefore include an indeterminate number of accidents whose causation is not in any way contributed to by fatigue, and whose distribution over the day may be such as to mask in the aggregate figures the effects of fatigue in those cases where it is a factor. Hence, in order to ascertain the effects of fatigue on accident causation, the method adopted by Bogardus in his analysis of the Illinois figures should be followed. The accident records were examined and the

[1] *American Journal of Sociology*, Vol. 17, 1911.

[2] Cited in Goldmark, in Bogardus; see also articles by Miss Hutchins in *Sociological Review*, Jan. 1913, and "Report on Conditions of Employment in the Iron and Steel Industry in the U.S.," Senate Document 110, Vol. IV.

accidents classified in two classes :—(*a*) those in which subjective conditions ("carelessness," &c.) could *in any way* have contributed to the accident; (*b*) those which were obviously due entirely to objective factors, *e.g.*, breakage of material or plant, flying shuttles, &c. What was desired was not to ascertain the percentage of accidents due to workers' negligence, but simply to eliminate those cases which were obviously due to causes outside the control on the day of the accident of any normal worker —not necessarily the injured person—engaged in his normal work. For example, an accident caused by the dropping of a brick from a scaffold by a bricklayer would be included in class (*a*), but an accident to the bricklayer due to the breakage of his scaffold would be included in class (*b*); for even though the breakage of the scaffold might have been due to negligence in constructing it, this presumably occurred at some time previous to the accident, and the significant time as regards the relation to fatigue would be the time of the construction of the scaffold, not the particular time at which it broke. As the former time is probably unknown, we eliminate the accident from class (*a*). In the case of the Illinois figures, class (*a*) amounted to about 82 per cent. of the whole. The time distribution of this class over the hours of the days of the week was then ascertained and stated in percentages.

Before even these figures can be utilised, a second difficulty must be faced. They relate to large numbers of factories, not all of which have the same starting, stopping, and meal-times. Hence an accident between 9 a.m.–10 a.m. may be in the third hour of work of Factory A., and in the second of Factory B. To some extent the difficulty is lessened if the figures are given in the form adopted by the German authorities, and classified according to their occurrence in the first, second, third hour of work, &c., but even here the meal-times may vary in their occurrence between the third and fourth, fourth and fifth hours. &c.

Hence, though the published statistics are exceedingly suggestive, I think they should be supplemented by the analysis of the records of large individual firms or groups of works whose hours and meal-times are similar and where the conditions of work are definitely known. The necessary particulars as to manner of occurrence, time, age of worker, will be easily obtainable from the Accidents Records kept for Factory and Compensation Act purposes. If a series of such returns for several large firms were obtained, it would probably furnish fairly definite information as to the influence of fatigue on accident occurrence,

especially if comparison were made of similar firms in the same industry working different hours. Possibly, too, additional information would be yielded by tracing the distribution of the accidents over the days of the week, and the variation before and after holidays, but the interpretation of such figures is complicated by the possibility that there may be considerable variations in the total number of workers employed on various days of the week, and correction for this would be difficult owing to the probable absence of records, and also to the further possibility that certain departments with accident risks differing from the normal may not be in full work on certain days of the week, *e.g.*, the ironing department in a factory laundry.

The foregoing statistical inquiries are really necessary for any complete investigation, but there are, of course, effects of fatigue in particular industries which, whilst not capable of statistical statement, may be even more important. Such effects are not confined to cases of excessive nervous strain, or of physical lesions such as varicose veins due to long standing, but may be more subtle in their incidence; for example, there seems to be some reason to believe that the onset of certain diseases, *e.g.*, pneumonia, may be in a large number of cases determined by fatigue. The full investigation of such effects requires medical knowledge, but it is desirable that their possibility should be borne in mind by the economic observer and attention directed to them, especially where the main objective determinants of fatigue—heavy muscular work, high wet-bulb temperature, long hours of work, &c.—are present, and the workers include a considerable percentage of women and young persons.

The lines of inquiry suggested above are, of course, by no means exhaustive, but though they are admittedly incomplete, yet they are beyond the powers of any one individual, or even of a small group of people, who can give only a part of their time to the inquiry. It is, therefore, to be hoped that the Fatigue Committee of the British Association will receive the co-operation of many other workers, and it is suggested that the carrying out of detailed inquiries along some such lines as the foregoing would afford valuable realistic experience to research students. Such co-operation would be heartily welcomed, and every possible assistance given to investigators by the secretaries to the Committee, Miss B. L. Hutchins and the writer.

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