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The simple reaction-time is the interval elapsing between the mental "receiving" of a sense-impression and the execution of a movement in response to that impression. Its consideration has of late occupied a somewhat prominent place in psycho-physical discussions. I propose here, first, to make clear the reason of the controversies which have arisen round this simplest question of mental chronometry; and, secondly, to attempt the proof that the matter at issue is really of psycho-physical importance, and that the final settlement of disputed points is for many reasons scientifically desirable.

(1) Ludwig Lange, working in Wundt's Institute at Leipsic in 1886-7 found that the duration of the simple reaction was appreciably different, according as the reagent directed his attention (so far as possible) exclusively upon the sense-impression or upon the movement to be made in response to it. Lange accordingly distinguished two types or forms of simple reaction, the *sensorial* and the *muscular.* He found also that a considerable amount of practice was necessary, if the reagent was to give each type in its extreme shape. Especially is[*sic*, probably "if"] there a tendency towards the shortening of the sensorial form by some intermixture of motor innervation: but the maximal degree of muscular preparation cannot either be attained all at once. The average difference between the two reactions is 0.1" = 100s.

This is the discovery which has led to so much psycho-physical controversy. I proceed to tabulate the principal evidence for and against its validity.

(*a*) L. Lange: *Phil. Stud.*, IV. pp. 479ff[-510]. *Sound* reactions. For three reagents, *m.*=125s, 137s, 123s; *s.*=223s, 224s, 230s. Difference: 98s; 87s, 107s. For one half-practised reagent, *m.*=147s; *s.*=192s. Difference: 45s. In the case of several (*zahlreiche*) other persons, altogether unpractised, the time-difference was found to exist without exception. Wundt quotes individual series of figures for *electrical-cutaneous* [p. 75] and *light* reactions from the as yet unpublished continuation of Lange's investigation (*Phys. Psych.*, 4th ed. II. p. 311). *Cutaneous*. For one reagent, *m.*=105 s; *s.*=213s. Difference: 108s. *Visual.* For two reagents, *m.*=172s,

182s; *s*.=290s, 291s. Difference: 118s, 109s.

(*b*) G. Martius: *Phil. Stud.*, VI. pp. 167ff[-216]. *Sound* reactions. For two unpractised reagents, *m.=130*s, 172s; *s*.=179s, 242s. Difference: 49s, 70s. The practised results of one of these reagents and of the writer (p. 210) cannot be appealed to, as the conditions of reaction had been modified (p. 211). Even with the modification, however, which greatly curtailed the sensorial time (changing it to a 'central' type), the latter proved invariably to be longer than the muscular.

(*c*) G. Dwelshauvers: *Phil. Stud.,* VI. pp. 217ff[-249]. *Sound* reactions. The tables of this observer are too lengthy to quote. I cite his summary: "The distinction drawn by L. Lange between the sensorial and muscular reaction ..... has proved entirely valid throughout my experiments. The difference is so considerable, that the shortest sensorial time exceeds the longest muscular by 60s" (p. 229).

(*d*) Lange's discrimination of the two reaction types suggested to O. Külpe the thought that the quality of the psycho-physical disposition would not be indifferent in the case of wholly automatic movements or coordinations. Hence arose the series of articles on the simultaneity of movement: *Phil. Stud.* VI. pp. 514ff[-535]., VI[*sic*, should be VII]. pp. 147ff[-168]. (Part III. still to be published). Cf. the author's *Grundriss der Psychologie,* pp. 422 ff.

(*e*) E. B. Titchener: *Phil. Stud.,* VIII. pp. 138 ff *Light* reactions. For three reagents, *m*.=178s, 181s, 182s; *s*.=260s, 266s, 279s. Difference: 82s, 85s, 97s. Seven participants in this investigation were found to be incapable of reacting with any degree of constancy: their results were therefore not employed. -- Cf. *Am. J. of Psych.,* VI. pp. 242 ff. *Sound* reactions. Four observers showed the typical difference with the ordinary key. Of eight tested with the Cattell lip-key, one was not educable; two gave central times for sensorial; and one could not be relied upon for constant results. The remaining four showed the typical difference. Of six tested with the Dessoir finger-key, two were not educable, and one gave central for sensorial times. Three, therefore, showed the typical difference.

(*f*) J. McK. Cattell: *Phil. Stud.* VIII. pp. 403ff. *Sound* reactions. For two observers no difference was found (105s, 105s; 105s,108s or 105s). *Cutaneous-electrical.* For two observers, no difference (142s, 142s; 119s, 121s); for one, the muscular time exceeds the sensorial (281s; 201s; difference [p. 76] 80s)! The first and third reagents were practised. -- Cf. *Psych. Rev.* I. p. 542, and p. 165 (no difference for two observers; muscular time exceeds sensorial for reagent mentioned above: all practised).

(*g*) J. J. van Biervliet: *Phil. Stud.* X. pp. 160ff. *Sound* reactions. The results of eleven observers are communicated, all under the rubric 'sensorial.' Two sets seem really sensorial; five central; four muscular. The mean variation seems in every case to be sensorial. The reagents were apparently not practised at all in muscular reactions.

(*h*) J. M. Baldwin: *Senses and Intellect,* p. 113. "If the attention be fixed upon the reacting sense rather than upon the receiving sense, the time is shorter.... This I found in my own experiments before seeing reference to N. (*sic*) Lange."

(*i*) M. Dessoir: *Arch. f.* [*Anat. und*] *Physiologie,* 1892, p. 311. Temporal relations of *contact* and *temperature,* and of the latter and *pain*. Of eight reagents, not one showed the sensorial-muscular difference. But the writer expressly states that they were not recommended to concentrate the attention exclusively upon impression or movement: "to react sensorially or muscularly" in obedience to such a recommendation "would be to react wrongly." "The true reaction stands midway between the two extremes." And the rubric for it (p. 312) reads just as does Martius' rubric for 'central' times. But if the observer is asked definitely for central times, it is not strange that he should avoid the sensorial-muscular extremes.

(*k*) C. B. Bliss: *Yale Studies,* I. pp. lff. *Sound* reactions. One reagent, practised exclusively in sensorial attention. Particular efforts towards the muscular form reduced the time

from 140s to 100s, and from 142s to 111s. "More often the time was lengthened. It seemed very difficult to overcome the habit of turning the attention toward the ear" (p. 38).

Here are ten witnesses. Six are positive; four more or less negative. But of the latter (*i*) is put out of court by his own evidence, and (*g*) and (*k*) by the fact that practice in muscular times had not been had. There are left the four observers of (*f*). Professor Cattell himself is so exceedingly practised a reagent, that one may suspect automatism in his case[1]. We have cases, again, in which the muscular time is the longer, recorded by Dr Martius[2] and Dr Bliss. The latter two writers offer an explanation of the phenomenon. Dr Martius refers it to the novelty of the stimulus, and the consequent inability to concentrate attention permanently on the movement. He has [p. 77] no doubt that with practice the normal relations of the two times would have been induced. To explain Professor Cattell's result we may adopt the theory that the reagent *D*[3] was naturally or by practice inclined to the sensorial type; supplementing it by the following hypothesis. It often happens that a beginner attends so strongly to the movement, that his hand is too highly innervated: the muscles become cramped, and the movement -- instead of being experienced as a *Befreiung* -- is more difficult and slower than in the sensorial reaction. This state of things can only be abolished by equalising practice between the two forms. Now plainly, a 'sensorial' reagent, turning perforce to the opposite mode, would be exceedingly apt to experience such an inhibition of movement.

Even the positive evidence, however, points to the fact that by no means every reagent showed the typical difference. On the basis of the whole, I have concluded that the distinction drawn by L. Lange is a valid one, but not obtainable from every observer. "Rather is there required for the work a special kind of disposition or *Anlage*".[4] Professor Cattell -- the principal opponent of Lange's view, as we have seen -- is a little amused at my '*Anlage*'.[5] He seems to have forgotten that the same point was made by Lange himself[6]; and has been since emphasised by Leumann[7], Külpe[8] and Wundt[9]. James, citing Buccola, suggests it[10]. Bolton has recently urged it very forcibly in a different connection[11]. So that Professor Cattell's sarcastic smile at Messrs. Hill and Watanabe must be made broad enough to include all these other investigators also.

(2) These, then, are the facts. I proceed to my second question:-- that of whether the matter at issue is of any real psychophysical importance. To answer this question, it will be necessary to review in brief the functions of the reaction experiment in the science.

(a) The reaction is the simplest type of a voluntary action. It, therefore, is the material which must be employed in the teaching or acquiring of introspective control of this combination of conscious processes. (b) The reaction method has been extensively employed for the determination of the duration [p. 78] and for the analysis of certain complex mental 'acts': cognition, discrimination, association, choice, etc. Thus, it has been called upon for proof that deduction is psychologically more difficult than induction. Subsumption takes less time than exemplification. To associate a word to a concrete impression occupies a shorter interval than to associate a concrete idea to a spoken name (Cattell, etc.). Other association laws have been confirmed by it: as, *e.g.* that the more immediate the temporal connection of two ideas is, the quicker it takes place (Trautscholdt, Münsterberg); or that the more nearly related an idea is to another, the more quickly does it connect with this other (Trautscholdt). As regards cognition, we have such important results as that the assimilation of a simple word takes no longer a time than that of a single letter (Cattell, Titchener). A fact of this description throws welcome light upon the 'mechanism' of mind. Again, the reaction method has been used, *e.g.* for the discrimination of degrees of tonal fusion. The minor third fuses less well than the major; the time of cognition of the former being constantly though not very much less than that of the latter (Tanzi). As regards discrimination proper, we find that qualities are distinguished much more easily than intensities (Friedrich, Tischer): the reaction method thus justifying the psychophysical assumption that quality is the most 'absolute attribute of a mental process, while our judgment of relative intensity is less ultimate, depending on a complicated chain of association. Lastly, that 'choice' takes time, over and above discrimination, is a fact of importance for conative theory[12].-- On the quantitative side, we have the time-values of the simple and compound reactions, which we can apply act norms in any particular case. The

shortening or lengthening of the simple time is correlated with certain pathological states of the nervous system (Kraepelin, etc.). The times of particular categories of association enable us to classify observers according to intellectual temperaments (Wundt, Münsterberg). And the duration of the reaction, once more, tells us whether a purporting association is a true association or an apperceptive completion(Titchener). (g) It has been suggested that "a man's reaction will show the influence of his memory type," as visual, auditory, motor or mixed (Baldwin, Flournoy). I do not wish to undervalue this suggestion, in which there may very probably 'be something':-- Professor Cattell genially alludes to it as the discovery of a kingdom, while my students' verification of the sensorial-muscular difference is a search for asses. But there will probably be difficulties in the way of the acceptance of the [p. 79] criterion as universally valid. For instance, I have myself cultivated the visualising power to a high degree, and have learned in the course of extended cutaneous investigation to control it pretty thoroughly. Yet my visual simple (sensorial) times, as is shown by several tests, are not shorter than the normal; nor is my auditory reaction longer. The muscular times, in both cases, are also normal. (d) It has been proposed to use the reaction-method for the determination of the duration of sensation. But the proposition has many difficulties, theoretical and practical, to contend with. (e) Reactions afford one of the best and surest means of investigating the psychophysics of practice. "We may study by their help the effects of practice; and not only its effects, but its progress, its distribution in time, and the variations in it which result from the nature of the acts experimented on and the personality of the observer[13]."The same holds of fatigue. (z) Again, the reaction-method can be turned to account in numerous ways for the investigation of the attention: in other ways, *i.e.,* than in that which is now *sub judice*, and which cannot therefore be insisted upon. I need only mention such topics as the fluctuations of attention, distraction, etc. (h) While, lastly, the reaction is employed in astronomy (observation of stellar transits), in physiology (propagation of nervous impulse[14], ocular accommodation, etc:), and, as hinted above, in pathology.

M. Binet seems, then, justified in his statement: *La psychométrie est une méthode générale*[15].

Now why is the settlement of the sensorial-muscular dispute desirable? Let us take in order the functions of the reaction-method which have been just cited. First, training in introspection of action. It is clear, that if there is to be any guarantee of progress in introspection, the experimenter must have some control: things cannot be left entirely to the experimentee, who is to be educated. I have elsewhere attempted to show that the sensorial times furnish such a control, while muscular times do not[16]. I will not here repeat the arguments adduced: they are all taken from actual experimentation. If they hold, it is very desirable that the sensorial form should be especially practised. Note also, that in the opinion of those who accept the sensorial-muscular distinction, the change of time-value as answer to the command to vary the direction of the attention is proof that the observer has his voluntary attention so far under control. [p. 80]

Secondly, analysis and temporal determination of complicated processes. It is clear, again, that the first step here must be the simple reaction. All compound forms imply and necessitate previous knowledge of the simple. When we ask which of the two forms is to be the basis of the further investigation, we meet with divergent answers. James says: "The 'extreme muscular method,' giving both the shortest times and the most constant ones, ought to be aimed at in all comparative investigations[17]." Wundt, while he admits the possibility of setting out from the muscular form, strongly recommends the employment of the sensorial[18]; and insists that the observer must be able to react with constancy in the two ways. Whichever view we adopt, this latter requirement must be made. For, on James' theory, the least complicated complication of the reflex reaction -- that, *i.e.,* in which the simplest psychical elements are introduced -- will be the sensorial. It, therefore, will be the next stage of practice after the muscular. And, on Wundt's, it is necessary (as stated) that the observer be able to react in both ways; since this is the only warrant that he can control his attention sufficiently to make it worth the experimenter's while to proceed with him to more difficult experimentation. This all from the qualitative standpoint. From the quantitative, as I have said above, the adoption of the one view or the other makes a time-difference of 100s in the results accepted.

For the study of the psychophysics of practice, the separation of the two forms is highly instructive. The muscular reaction tends to become automatic and reflexlike; this tendency being very much weaker for the sensorial. So with fatigue; the 'muscular' fatigue, when practice has attained its maximum, is principally motor, the 'sensorial' mental.

Attention is debatable ground: and as I hope that my case is already made out, I will not enter upon a discussion of it. It will be readily seen that the comparative psychological value of a distraction, *e.g.,* cannot be estimated, if the reaction-form vary from individual to individual, or with the same individual at different times; even although (and for this we have found the valid evidence to be exceedingly little) the time-values should turn out to be the same in either case.

(3) The psychophysical importance of the controverted issue has now been set forth. I append as postscript a table of the introspective differences between the two forms of the simple reaction, as taught in the Leipsic Institute. [p. 81]

Muscular	*Sensorial*
(i) Motor attention, expectation,assimilation.	(i) Sensory attention, expectation, assimilation.
(ii) Motor strain sensations.	(ii) Sensory strain sensations.
(iii) Reflexlike, spasmic movement.	(iii) Willed, slow movement.
(iv) Simple perception of impression, with previous act of will.	(iv) Apperception of impression, with consequent act of will.
(v) Premature and erroneous	(v) No mistakes.

The stages in the theory of the simple reaction, up to 1892, I have already discussed in *Mind*, N.S. I. pp. 216ff. The more important publications upon the question since that time are as follows: Cattell, *P. S.* VIII., 403; Külpe, *Grundriss,* 421; Exner, *Entwurf einer physiologischen Eklärung der psychischen Erscheinungen,* I., 156. Compound reactions are discussed from the point of view of theory by Külpe, 825; Wundt, Kraepelin, Merkel, *P.* S. X.,485; and Exner, 160. Incidental contributions to theory are made in several of the papers cited above.

Footnotes

[1] Wundt, *Phys. Psych.,* 4te Aufl. II. 316, 317.

[2] *P.S..,* VI. p. 409.

[3] At the time of testing, *D* had reacted to about 2000 electrical stimulations, without knowing of the sensorial-muscular difference: *P.S.,* VIII. p. 406.

[4] *Am. J. of Psych.,* VI. p. 246.

[5] *Psych. Rev.,* I. p. 543.

[6] *P.S.,* IV. pp. 494, 495.

[7] *P.S.,* V. p. 631.

[8] G*rundriss,* pp. 422, 423.

[9] *P. P.,* 4te Aufl., II. pp. 312 ff., esp. p. 321. And Vorlesungen, 2te Aufl., p. 298.

[10] *Principles*, I. p. 94.

[11] Rhythm: *Am. J. of Psych.,* VI. pp. 208 ff.

[12] See Wundt, Merkel and Kraepelin, *P. S.*, X. pp. 485 ff.

[13] Binet, *Psychologie expérimentale,* p. 127.

[14] Partially discredited by Professors Cattell and Dolley ; *Psych. Rev.,* I., pp. 159ff., esp. p. 168.

[15] *Op. cit.,* p. 130.

[16] *Am. J. of Psych,* VI. pp. 408 ff.

[17] *Principles,* I. pp. 93, 94.

[18] *Phys. Psych.,* 4te Aufl, I. pp. 362, 388; 344; 370.

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