Whereas the two first determinations were easily made, we met in the third with a serious difficulty, which made us refrain from further experiments above 35°.2. The solution point of the last distillate lies namely at 37°.2, so on the almost horizontal part of the solubility curve. Thereby, the determination of the concentration in this manner becomes inexact, which would become still worse at the higher temperatures. We have checked it for this distillate by adding a weighed quantity of carbon disulphide, altering thereby the composition and the solution point so as to bring them on to a part of the solubility curve, which is more easily determined. No important difference was found.

The experiments carried out show, however, clearly, that this system does not afford a plain proof of the theory. Although we see that the vapour line after extrapolation cuts the solubility curve at 32 molproc., whilst the critical point lies at 36°/₀, the temperatures of the intersection point and the critical point cannot be distinguished. The course of the curves being so unfavourable for our purpose, we decided to take no more experiments with this system. Our result is remarkable in this point: although the theory proves, that the vapour branch does not leave the region of limited miscibility in the critical point, the opinion previously expressed that this had to be the case, is not very far from the truth.

Inorg. Chem. Laboratory
University of Amsterdam.

Experimental Psychology. "— *Intercomparison of some results obtained in the Investigation of Memory by the Natural and the Experimental Learning-Method*". By Dr. F. ROELS. (Communicated by Prof. C. WINKLER).

(Communicated in the meeting of March 31, 1917.)

In the investigation of memory psychologists have always had recourse to learning-experiments, with the purpose to ascertain, under definite experimental conditions, the retentive capacity of the memory with regard to the material impressed upon it. Whatever method was employed (the learning-, or the saving- or the hitting-, or the helping-method) the imprinting occurred invariably in the same way. The material to be learned, by preference meaningless, was presented to the observer at a certain rate of succession, and more or less frequently, according to the object in view. Psychologists did not always take into account the learning-method peculiar to every

individual so that now and again the rate of succession of the terms corresponded little with the time required by the observer to spontaneously take in the material presented. The difficulties arising from this, which are felt in individual psychological experiments much more strongly than in general investigations, do perhaps not render the results, achieved in this way, totally invalid. Nevertheless, viewed more closely, they appear to me weighty enough to justify an intercomparison of the results obtained by the natural and the experimental method.

The results reported in this paper have been obtained in a series of experiments performed in the Psychological Laboratory of the Utrecht Clinic for Psychiatry and Neurology. The course of the experiments was regulated as follows:

Three observers (M, R and D) committed to memory 40 series of 12 nonsense-syllables. For the first twenty (Group I) the observer was at liberty to choose his own rate of succession, to group the syllables, to determine the interval between two successive repetitions etc. all in his own way. The only restrictions he had to submit to were that in the successive repetitions he was allowed to pronounce a syllable only once, and that when once his attention had averted from a syllable, it should on no account return to it again. The other 20 series (Group II) were exhibited by means of a mnemometer of our own construction. It consisted of a drum, rotating evenly and at a carefully tested speed about an horizontal axis by the help of a HELMHOLTZ electromotor. On this drum was wound a strip of paper printed with the syllables at equal distances. Before the drum there was a screen with a slit in the centre past which the syllables flitted in succession when the drum was turned round. Thus the time of exposure was the same for each syllable, so were the intervals between two successive syllables, so also were those between two successive repetitions.

In the experiments of Group I as well as those of Group II the observer spoke through a voice-key, consisting of the diaphragm of a gramophone, to which a platinum disc had been attached. On this disc rested the platinum-covered point of a V-shaped arm, which was turning about an horizontal axis, and easily adjustable by the help of a sliding weight. The deflections of this arm broke the electric current flowing through the instrument even with the slightest intensity of the spoken sound on the diaphraghm. These breaks were registered by a marking magnet upon the drum of a kymographion. A second magnet drew a time-line ($^1/_5$ sec.) with the aid of KAGENAAR'S chronoscope. We were thus enabled to determine by the

natural and the experimental method the duration of every repetition, the time relation between the successive terms of one series, and its modification with the progress of the process of learning etc.

The determination of the time required for every repetition and for the whole learning-process involved some difficulty as our voice-key, though it indicated distinctly the moment when the observer started the first syllable of a series, did not precisely report the moment when the reading of the last syllable was completed. However, we have ignored this source of experimental error in our calculations, seeing that the moment at which the last syllable is begun is easy of determination and only a minimal time (at the most 0,2 sec.) is required to pronounce a syllable consisting of two consonants with a vowel or a diphthong between them. This may the more readily be done since it equally affects the time-values in both groups (I and II).

In the experiments of Group II we had to look out for the moment the first syllable appeared in the slit as it need not coincide with the moment when the observer reads it. We, therefore, fitted to one side of the drum of the mnemometer a button, which, whenever the drum had come round again to its starting point, came in contact with a spring. With this contact we made the appearance of the first syllable coincide. The breaking of the circuit brought about by the contact was registered by means of a marking magnet on the drum of a kymographion.

If the observer supposed he knew the series, he said it by heart. In case he broke down the experimenter presented the rest of the series once more. Close upon the recitation the observer told how he had proceeded in learning the syllables, how he had grouped his material, what associative connections he had made between the syllables.

Every day four series were committed to memory. Precisely 24 hours later we ascertained by the saving-method how much of the impressed material of the previous day had stuck. Group I was gone through unintermittently; not before this was got through did we start the second group.

The subjoined table shows the mean number of repetitions which the several observers required to learn a series by the natural- (I), and by the experimental (II) method. For each observer the first and the third horizontal row shows the results of the learning-experiments (l) of the first day; the second and the fourth those of the repetition-experiments (r) 24 hours later. Alongside of the arithmetical mean we also tabulated the mean deviation and the median.

The last column illustrates the gain (expressed in percentages) realised after 24 hours by the natural- and by the experimental method. We also add a column for the number of series learned by heart.

TABLE I.

Observers	*Number of series*			*Arithm. mean*	*Mean deviation*	*Median*	*Gain after 24 hours*
M.	20	I	l	8.45	1.50	8	52.77
			r	4	0.46	4	
	20	II	l	9.25	1.41	9	47.03
			r	4.90	0.95	5	
R.	20	I	l	4.50	1.04	4	45.56
			r	2.45	0.78	2	
	20	II	l	7.60	1.50	7.50	59.21
			r	3.10	0.74	3	
D.	20	I	l	9.66	2.08	9	49.28
			r	4.90	0.80	5.50	
	8	II	l	10.50	3.25	9.50	46.43
			r	5.60	1.92	4.50	

The order of the observers relative to the number of repetitions in group I is maintained in group II. For each of them the number of the repetitions increases; for M. and D. in about the same degree (respectively 9,47 and 8,69 percent); for R the increase is much greater (68.89 perc.). A similar process is observed in the *r*-rows. Here also the increase is greatest for R (26.53 perc.), much less for D than for M (respectively 14.28 and 22.5 perc.).

The percentage of repetitions saved after 24 hours is for M and D higher in I than in II (respectively 52.77; 47.03 and 49.28; 46.43 perc.). The reverse is observed in the case of R, for whom II yields a considerably larger gain (59.21 and 45.56 perc.).

The second Table gives the average time required for getting a series by heart in group I and II. After what we said about the preceding table we need not enter into further details about its construction. The time-values are expressed in seconds.

With II the time of the learning-experiments decreases, for M and D respectively 5.28 and 14.74 perc. R, however, requires more

TABLE II.

Observers	Number of series			Arithm. mean	Mean deviation	Median	Gain after 24 hours
M.	19	I	l	92.40	15.67	87.45	53.05
	20		r	43.38	6.91	44.55	
	20	II	l	87.52	11.83	88.12	47.44
	20		r	46	8.48	43.40	
R.	20	I	l	61.43	16.15	57.97	52.89
	20		r	28.94	9.55	26.97	
	19	II	l	70.23	11.38	71.85	60.17
	19		r	27.97	6.54	26.75	
D.	17	I	l	114.40	32.36	86.85	51.70
	20		r	55.26	13.54	55.47	
	8	II	l	97.54	21.79	89.23	48.64
	8		r	50.10	14.21	43.20	

time with II (increase 14.32 perc.). The learning-times of the *r*-rows do not differ very much. For R and D they decrease with II (respectively 3.35 and 9.34 perc.) for M the increase is 6.04 perc. For M and D the time saved after 24 hours is greater with I (respectively 53.05; 47.44 and 51.70; 48.64 perc.); for R, however, considerably greater with II (52.89 and 60.17 perc.).

When summarising these data we see that the number of repetitions needed to learn the series by heart is larger with II than with I, in the learning- as well as in the repetition-experiments. The increase of the number of repetitions in the learning-experiments does not keep pace with that of the repetition-experiments, so that for two of our observers the gain after 24 hours is largest with I, for the third with II. Again, with II the learning does not only require less time, the gain effected after 24 hours is also greater. The few exceptions may be accounted for by the unequal increment in the number of repetitions in the learning- as well as in the repetition-experiments.

The third Table gives the mean duration of the recitation-times (seconds) in the learning- and the repetition-experiments with I and II along with the gain effected after 24 hours in percentages.

For all observers the recitation-time of the learning-experiments is longer than that of the repetition-experiments, with I as well as

TABLE III.

Observers	Number of series			Arithm. mean	Mean deviation	Median	Gain after 24 hours
M.	20	I	l	13.61	3.31	12.37	13.74
	20		r	11.74	2.24	10.95	
	20	II	l	11.49	2.19	10.47	4.96
	20		r	10.92	2.25	10.07	
R.	20	I	l	11.95	3.73	11.25	2.43
	20		r	11.66	2.21	11.65	
	19	II	l	13.92	4.57	12.63	19.04
	20		r	11.27	2.62	10.65	
D.	17	I	l	11.54	1.98	11.10	14.30
	20		r	9.89	1.79	9.30	
	8	II	l	11.15	2.98	10.78	3.14
	8		r	10.75	1.95	10.45	

with II. M. and D recite quicker with II. R, on the contrary quicker with I. This at least is the case in the learning-experiments. The recitation of the repetition-experiments lasts longer with II than with I only in the case of D. The column of percentages of repetitions saved after 24 hours with I and II clearly shows that the gain is greater with I for M and D; for R however, with II. — Consequently the recitation-time with I as well as with II is longer in the learning-experiments than in the repetition-experiments. Again, as to furthering a quick recitation the experimental method seems to have the advantage over the natural, whereas the latter yields a greater gain.

The mean rate of succession of the presentations of the series of the second group, measured from the moment when the first syllable appeared in the slit of the mnemometer to the appearance of the last was 9,5 seconds. The next table shows how the observers themselves determined spontaneously the rate of succession in the learning- and the repetition-experiments. We determined accordingly the mean duration of a repetition in the learning- and in the repetition-experiments. The first column gives the number of repetitions, from which the time-values have been calculated.

For R. and D. the mean duration of a repetition is markedly

TABLE IV.

Observers	Number of Repetition		Arithm. mean	Mean deviation	Median
M.	167	l	11.26	1.03	10.87
	80	r	11.31	1.21	11.47
R.	86	l	13.44	1.40	12.95
	49	r	11.79	1.08	11.66
D.	173	l	11.16	1.40	10.44
	110	r	9.86	1.39	9.71

greater for the learning- than for the repetition-experiments; for M. they are almost equal. For learning as well as for repeating a repetition requires on the average more time with I than with II. Only in the case of repeating does the average duration of a repetition for M. approximate to that of I.

The following tables illustrate how the observers modified the rate of succession spontaneously according as they were getting more familiar with the material. For every series we divided the repetitions necessary to learn the material by heart (learning and repetition) into three groups of successive repetitions. For each group we calculated the mean duration of its repetitions. A comparison of the time-values of each group shows the changes in the rate of succession in learning and repetition concurring with the greater familiarity on the part of the observer with the material to be impressed. It should be observed that, when the number of repetitions was not divisible by three, the first and the last group always contained the same number of repetitions which made the middle group longer or shorter by one repetition. Though the time of exposure of the syllables, as established by the mnemometer was always the same with II the observer had ample opportunity to lengthen or to shorten the duration of the repetitions to a certain extent, as he was at liberty to read the first and the last syllable of the series at any moment of the period during which they remained visible in the slit. So with II there may also be a tendency to shorten or to lengthen the duration of the repetitions as the learning-process advances.

Apart from a few exceptions for D, the duration of the repetitions increases according as the observer is getting more familiar with the material to be impressed, in the learning- as well as in

TABLE V. *Observer M.*

	Groups		*Arithm. mean*	*Mean deviation*	*Median*
I (20)	1st	l	9.79	0.63	9.72
		r	9.34	0.68	9.70
	2d	l	10.92	0.86	10.93
		r	10.78	0.92	10.72
	3d	l	12.57	1.66	11.82
		r	12.73	2.03	12.27
II (20)	1st	l	9.62	0.51	9.37
		r	9.52	0.60	9.31
	2d	l	9.57	0.52	9.47
		r	9.52	0.51	9.30
	3d	l	9.50	0.49	9.47
		r	9.49	0.55	9.40

TABLE VI. *Observer R.*

	Groups		*Arithm. mean*	*Mean deviation*	*Median*
I (20)	1st	l	12.42	0.71	12.57
		r	10.91	1.33	11.20
	2d	l	13.33	1.33	13.55
		r	11.10	1.78	10.50
	3d	l	14.13	2.41	13.56
		r	13.28	1.78	12.90
II (19)	1st	l	9.22	0.78	9.22
		r	9.11	0.44	9.10
	2d	l	9.09	0.99	9.08
		r	9.52	0.84	8.80
	3d	I	9.56	1.02	9.83
		r	9	1.02	9.35

TABLE VII. *Observer D.*

	Groups		Arithm. mean	Mean deviation	Median
I (20)	1st	l	11.09	1.33	10.62
		r	9.82	1.49	9.70
	2d	l	10.70	1.33	10.35
		r	10.12	1.74	9.55
	3d	l	11.49	1.89	11.13
		r	10.11	1.58	10.25
II (8)	1st	l	9.76	0.53	9.76
		r	9.53	0.22	9.51
	2d	l	9.69	0.59	9.58
		r	9.22	0.37	9.22
	3d	l	9.67	0.67	9.50
		r	9.33	0.42	9.31

the repetition-experiments. Again with one exception for D the increase is greater in the repetition- than in the learning-experiments (for M. 3.39 and 2.78; for R. 2.77 and 1.71 sec.); this proves again that with at least two of our observers there is a tendency to lengthen the learning-time, when the knowledge of the material has increased in consequence of the repetition-experiments of the previous day. It is also proved by the fact that with a few exceptions, the lengthening of the learning-time, in the learning- as well as in the repetition-experiments is greater when passing from the II^{d} to the III^{d} than from the Ist to the II^{d} group. (for M. 1.13 and 165; 1.44 and 1.95 sec.; for R. 0.91 and 0.80; 0.19 and 2.81; sec.; for D.: — 0.39 and 0.79; 0.30 and — 0.01 sec.) It seems advisible to conclude, therefore, that with I for two of our three observers the time required for succession-repetitions increases as well in the learning- as in the repetition-experiments, when the observer gets more familiar with the material. With II there is no gradual increase at all with a fuller knowledge of the material. As with I, the time-values are indeed, generally smaller in the repetition- than in the learning-experiments, but where, as e. g. with I the mean duration of the repetition of the last group is always the longest, it is always the shortest with group II, with a few exceptions only. For the

rest a comparison of the time-values of the several groups does not reveal any similarity.

TABLE VIII.

Observers		*Groups*		*Arithm. mean*	*Mean deviation*	*Median*
M.	I	1st	l	8.90	1.70	8.50
			r	3.90	0.36	4
		2d	l	8	1.30	8.50
			r	4.10	0.56	4
	II	1st	l	10.40	1.32	11
			r	5.80	1.30	5
		2d	l	8.10	1.50	8.50
			r	4	0.60	4
R.	I	1st	l	5.40	1.40	5.50
			r	2.60	0.80	2.50
		2d	l	3.60	0.68	4
			r	2.30	0.76	2.50
	II	1st	l	8.20	1.40	7.50
			r	3.10	0.74	3
		2d	l	7	1.60	7.50
			r	3.10	0.74	3
D.	I	1st	l	10.62	2.37	10
			r	5.80	1.16	6
		2d	l	8.70	1.80	8
			r	4	0.44	4

The tables VIII and IX illustrate the influence that practice exerts upon the number of repetitions and upon the learning-time with I and II in the learning- as well as in the repetition-experiments. In tabulating the data obtained in the learning- and repetition-experiments as regards the number of repetitions and the learning-time, they have been arranged in the order in which they were acquired and have then been split into two equal groups. For every group we calculated the arithmetical mean, the mean deviation and the median. The figures of table VIII refer to number of repetitions,

those of table IX to the time-values, expressed in seconds. The data for D with II, being too small numerically could not be tabulated.

Table VIII clearly shows that the influence of practice reveals itself in a decrease of the number of repetitions. With I the number of repetitions required to learn the series by heart is smaller in the second group than in the first, (for M 10 °/₀; R 33 °/₀ and D 17.93 °/₀.) With II a similar gain is effected (for M 22 perc. for D 15 pct.). For the former, therefore, the influence is greater, for the latter, smaller with II than with I.

The values obtained in the repetition-experiments are not suitable for comparison as their significance depends for the greater part on their relation to those of the learning-experiments. We, therefore,

TABLE IX.

Observers		*Groups*		*Arithm. mean*	*Mean deviation*	*Median*
M.	I	1st	l	90.25	16.54	86.95
			r	36.02	5.89	41.15
		2d	l	94.55	14.80	94.37
			r	50.75	7.93	49.92
	II	1st	l	97.11	10.48	100.37
			r	53.31	11.23	49.62
		2d	l	77.99	13.18	80.47
			r	38.69	5.74	39.92
R.	I	1st	l	75.43	21.16	66.65
			r	28.56	8.80	26.80
		2d	I	47.44	11.15	51.82
			r	29.32	10.31	27.33
	II	1st	l	78.83	12.13	74.25
			r	31.21	8.84	28.90
		2d	l	61.64	10.64	62.85
			r	24.74	4.25	23.60
D.	I	1st	l	138.19	42.22	133.60
			r	68.70	12.74	65.02
		2d	l	90.61	22.50	79.70
			r	41.81	14.35	33.02

calculate the gain effected with I and II in the repetition-experiments of the first and the second group. This gain is expressed in percentages in the following table.

TABLE X.

Observers	*Groups*	I	II
M.	1st	56.15	44.33
	2d	48.75	51.62
R.	1st	51.85	62.20
	2d	36.11	55.72
D.	1st	45.29	—
	2d	54.05	—

For M and D the gain lessens with I. The learning of the series of the second group requires, it is true, fewer repetitions but the decrease of the number of repetitions in the repetition-experiments does not run parallel to it, so that after all the gain turns out to be smaller. D, who sat down for the first time to an experimental investigation of the memory, learns the series of the second group not only with fewer repetitions, but also furnishes a greater gain in the repetition-experiments, a phenomenon due to his inexperience, which made him more susceptible than the others to the favourable influence of practice and of the repetition of the experiments.

With II the influence of practice is noticeable for R in a fall of the percentage of repetitions saved; for M however, this percentage rises. Most likely the difference between those two observers is due to the fact that with II R tried to translate the rate of succession, which did not suit him, into his own, in which, of course, he succeeded only after some training. M, on the other hand, scrupulously stuck to the experimental rate all through the experiments with II.

The influence of practice on the learning-time (Table IX) appears for R and D generally in a decrease of the latter. This applies to I as well as to II, to the learning- as well as to the repetition-experiments. Whereas for R with I the number of repetitions in the learning-experiment decreases (33 perc.), the decrease in time is 37,11 perc., for D the decrease is respectively 17,03 perc. and 34 perc. For D the number of repetitions with I decreases in the repetition-experiments 31,04 perc., the learning-time 39,14 perc., so that here also the influence of practice is shown in a shorter learning-time;

for R however, the number of repetitions lessens 2,66 perc., so that under the influence of practice the learning-time increases. With I the learning-time for R in the second group increases in the learning-experiments as well as in the repetition-experiments; the number of repetitions and the time increase respectively 15 and 21,81 and 0 and 21,05 perc. The influence of practice reveals itself for M invariably in a longer learning time. The decrease of the number of repetitions and in the learning-time is in the learning- and in the repeating-experiments with I and II respectively 10 and + 4.76 perc., + 5.13 and + 40.89 perc., 22 and 19,69 perc., 31.04 and 27.43 perc.

The striking difference between M and the other two observers in relation to the influence of practice upon the learning-time is due to the fact that M proceeds in the learning-experiment in a different way from R and D. Whereas the latter on getting more familiar with the material, go on reading, M directly starts his recitation when he is able to do so. It is not that R and D do not recite the familiar syllables, they even like to begin, however not with the same energy as is the case with M. Under the influence of practice the observer familiarizes himself sooner with the syllables, which, given the tendency to recite as quickly as possible, soon induces him to alternate reading with reciting. The consequence, however, is that the learning-time is lengthened.

It is worthy of notice that, as shown by M's percentages, the natural method is more adapted to M's way of learning than the experimental. This is easy to understand, if we consider that the observer, if he will not run the risk of disturbing the learning-process, is compelled by the experimental rate to give up looking for a syllable, when, at the appearance of the following in the mnemometer, it has not yet been brought to consciousness.

Summarizing then, the data of the last three tables yield the following results: The influence of practice reveals itself in the learning-experiments in a decrease of the number of repetitions required for the process of learning. For M it is greater with II; for R, on the other hand, with I. In the repetition-experiments the gain lessens for M. and for R. D, however, saves repetitions, which is due to this observer being a novice in psychological experimentation. The lower percentage of repetitions saved with II for R under the influence of practice is probably due to the fact that with I this observer tried to translate the experimental rate which did not suit him, into the rate peculiar to his own method of learning, in which he succeeded only after sufficient practice. The influence of practice upon the learning-time is generally shown for R and D in

a shorter time required for learning. For M however, the learning-time is lengthened, which is to be ascribed to the strong tendency to recite the familiar syllables. With I this tendency is more persistent than with II.

CONCLUSIONS.

1. The number of repetitions required for learning the material by heart in the learning- as well as in the repetition-experiments is larger with the experimental method than with the natural. The increase in the number of repetitions in the learning-experiments does not, however, run parallel to that of the repetition experiments, so that for two of our observers the gain effected after 24 hours is greatest with the natural method; for the third, however, with the experimental.

2. With the experimental method the learning of the material does not only require less time, also more time is saved after 24 hours. Some exceptions are accounted for by the differing increases of the number of repetitions required for the learning in the learning- and the repetition-experiments.

3. The recitation time, whether the natural or the experimental method be employed, is longer in the learning than in the repetition-experiments. The experimental method seems to be more adapted to a quick recitation than the natural. The latter, on the other hand is more economising.

4. As a rule the mean duration of a repetition is longer in the learning- than in the repetition-experiments. The natural rate of succession of our observers appeared to be considerably slower than the experimental.

5. With the natural method the rate of succession with two of our three observers, in the learning- as well as in the repetition-experiments is slowing gradually when they get more familiar with the material. With the experimental method this slowing process is entirely out of the question. True, here also the rate of succession is generally quicker in the repetition- than in the learning-experiments.

6. The effect of practice is shown in a decrease of the number of repetitions required for learning the material by heart. For one observer it is greatest with the experimental method, for the other with the natural.

7. The effect of practice upon the learning-time with the natural as well as with the experimental method, generally manifests itself in a shorter learning-time. A lengthening in the case of one of our observers must be ascribed to a strong tendency to recite the familiar syllables, which persists more readily with the natural than with the experimental method.