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EDITORIAL

Psychotechnik, human factors, engineering psychology, Technikpsychologie—100 years of interdisciplinary cooperation between engineering and human sciences

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Psychotechnik, Humanfaktoren, Ingenieurpsychologie, Technikpsychologie – 100 Jahre interdisziplinäre Zusammenarbeit von Ingenieur- und Humanwissenschaften

1 Introduction

This special issue was edited by Joachim Vogt and Nina Gerber on the occasion of the 100th anniversary of the foundation of the Psychotechnik Institut at The Applied University of Technology in Darmstadt, Germany 1922. The institute was closed shortly after but the work continues in Darmstadt's Institute of Ergonomics and Human Factors as well as Work and Engineering Psychology Research Group. We are proud to present a lot of high quality, state of the art, interdisciplinary research of psychologists and engineers, many of them with roots in Darmstadt. We open with two editorial articles. This first one by Vogt et al. describes how the field developed from experimental psychology and spread into many application fields. The second by Gerber et al. will build bridges to the following articles coming from colleagues all over Europe. We hope that this is a valuable contribution to the history and further development of our field.

Since the dawn of mankind, a co-development of humans and technology took place. Especially the upright gait enabled tool use. The transition from Stone to Internet Age (Jäncke 2021) happens in waves and adaptive difficulties often iterate. During the last century, this co-development has been scientifically accompanied by psychologists. The following section zooms in and out on some of these developments with a focus on Darmstadt and Germany but also looks beyond.

Psychotechnik as a term was introduced in 1903 by William Stern (Weinberger 2021). Famous German psychologists like Münsterberg, Moede, and Giese used Psychotechnik to describe human adaption to industrial processes (Subjektpsychotechnik) and vice versa.

Psychotechnik today is understood as, for example, observation, survey, interview, and test methods. The subsections of most areas of psychology start with the special, non-psychology part like, for example, Architectural Psychology, Biological Psychology, Clinical Psychology. Industry uses the term Human Factors to describe and investigate in a deficit view (negative) incidents and accidents in the interaction of humans with machines. However, there is the other side of the coin, where humans against all odds (Vogt and Kastner 2002) manage complex socio-technical systems well even in degraded modes. Engineering psychology tries to design such socio-technical systems in a way that humans intuitively operate the machines safely to prevent accidents (positive view). In our opinion, the two sub terms Psycho and Technik have to change positions to TECHNIKPSYCHOLOGIE. Thus, we have a term constructed in line with the other psychological subsections: specific, non-psychology term first. Moreover, Technikpsychologie is a neutral term and includes both, human strength and weakness. Therefore, it should be used as the superior term.

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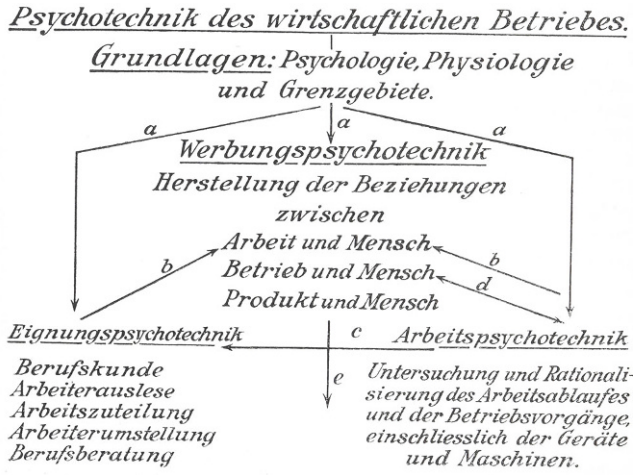

Fig. 1 Psychotechnik as a teaching course as conceived by Erwin Bramesfeld (1926)

Technikpsychologie is a fixed term in the German Dictionary of Psychology, defined as the science of relationships between humans and technologies (Weinberger 2021). Weinberger emphasizes that technology is human-made and in turn teaches (through trial and error) and develops humans. This co-development is described in a terminology considering benefits and conflicts.

Technikpsychologie at work investigates and rationalizes human behaviour at work in organizations. Figure 1 shows Bramesfeld's (1926) structuring of the field: Technikpsychologie in selection (recruitment, selection, training) helps finding the right people for a job by considering the Berufskunde (professions requirements), the Arbeiterauslese (selection of workers), Arbeiterumstellung (on-the-new-job training), and Berufsberatung (career counselling). Like we today, Bramesfeld distinguished basic subjects like physiology to be taught before fostering on-the-job applications.

1.1 Historical development of Technikpsychologie

Industrialization moved the craftsmen's work to mass production (Industry 1.0) in the late 19th and the early 20th century. The following Industry 2.0 contained the development of production lines and piece-rate work. Before industrialization, psychology was in many places a section of philosophy. Industry 1.0 and 2.0 pushed psychology in the science and engineering direction. The car industry, in person e.g. Henry Ford, was as often in history the pioneering branch. The development was fostered by the Scientific Management, Frederick Winslow Taylor's (1856–1915) concept of dividing the work process into the tiniest possible steps and hand movements. He measured the time needed for each step to optimize processes and payment. His governing principle "a fair pay for a fair day's work" shows that his intention was human-centred—before Scientific Management, gang leaders exploited workers by labour leasing them to factory owners. Human enhancement has been debated from many ethical and political points of view as well as from literature perspectives (Coenen et al. 2010). Already these early times saw a connection between work conditions and workers' health. Mergers, reorganizations, and change of companies challenged human performance and health since Industry 1.0 until today (Kotter 1996). In 2018, Thomson and Michel (2018) stated that especially rapid, maybe immature, changes of work conditions and organization, are responsible for health impairments.

At about the same time, psychology became its own science with physics as a role model at many universities. The paradigm changed from introspection and reasoning to the experiment as the core method and scientific approach of psychology. Most psychological institutes in Germany still follow this line, especially those at technical universities. In Germany, the universities of technology with regular, full-time psychology Bachelor and Master of Science curricula (without distance learning before Corona), are located in Aachen, Braunschweig, Chemnitz, Darmstadt, Dortmund (Master of Education), and Dresden.

Psychology institutes with socio-technical rather than philosophical approaches emerged around the end of the 19th and the beginning of the 20th century all over Germany. Here are a few examples in chronological order:

- 1867: Munich, Ludwig-Maximilians-Universität; as part of philosophy, the first chair of pedagogics and psychology was founded
- 1879: Leipzig, Wilhelm Wundt founded the first psychological laboratory and detached psychology from philosophy; his house is currently being restored: http://www.wilhelm-wundt-haus.de
- 1887: Göttingen, Georg Elias Müller founded the second psychological laboratory: https://www.spektrum.de/lexikon/psychologie/mueller-georg-elias/10080
- 1896: Würzburg; Oswald Külpe, formerly assistant to Wilhelm Wundt in Leipzig, founded another laboratory in Würzburg. Külpe and his colleagues developed a new psychological experimentation that challenged many of Wundt's restrictions. In the Würzburg experiments, the subjects were exposed to complex stimuli and after processing these for a time, they reported to the experimenter everything that came across their minds. Today, we call this a stimulus recall interview (or report). Karl Popper visited lectures of Bühler and Selz, and in his philosophy of science, the Würzburg School is noticeable. On the occasion of the Würzburg Institute's 125 anniversary, the Adolf-Würth-Centre offered a virtual exhibition: https://www.uni-wuerzburg.de/awz/news/news/single/

news/wie-wagt-man-eine-neue-ausstellung-in-zeiten-von-corona/

- 1922: Darmstadt, Institut für Psychotechnik, Erwin Bramesfeld, see above and below

Similar developments took place all over Europe, here a few examples:

- 1870: Zurich: Implementation of a second philosophy chair and the transition from idealism (all phenomena are ideas) to materialism (everything is physical). 1914 the psychological institute was founded (Maercker 2007).
- 1889: Paris; Théodule Ribot (1839–1916) is credited as the father of French psychology (Plesa 2022). He founded the first French experimental laboratory at Collège de France. Before, in 1884, he initiated the Society for Physiological Psychology. In 1889, Ribot hosted the First International Congress of Psychology. The International Union of Psychological Science IUPsyS emerged from this Congress. The IUPsyS still sponsors an International Congress of Psychology (ICP) every four years (International Union of Psychological Science, iupsys.net)
- 1886: Copenhagen: Alfred Lehmann https://psy.ku.dk/om/Historie/ founded the "Psychofysiske Laboratorium" a psychophysiology lab. It was integrated into the University of Copenhagen in 1903. Centrifuge treatments of mentally sick people were already investigated in 1753 by Kratzenstein, a German physics professor in Copenhagen (Ellehøj et al. 1979).
- 1894: Graz: Alexius Meinong founded the first psychological laboratory in Austria-Hungary https://psychologie.uni-graz.at/de/institut/geschichte/institutsgeschichte/
- 1921: National Institute of Industrial Psychology (NIIP). Charles Myers founded NIIP in 1920 and was appointed the institute's first director (1920). The British Psychological Society began opening to industry and all other people interested in psychology ("psychology for all"; Jackson 2019). The NIIP coined British occupational psychology like no other institution. As a strategic goal, the NIIP should "promote by systematic scientific methods a more effective application of human energy in occupational life ... and a higher standard of comfort and welfare for the workers." The NIIP existed until 1973. It later continued to work on a smaller scale until it finally closed in 1976 (BPS 2021).

Landau (2013) spotted the origin of the Darmstadt Psychotechnik-Institut in 1894, when the Laboratory of Technology and Machine Tools was established. Also, in 1894, Heinrich Krauß, head of that laboratory, hold the first lecture on "Arbeitsschutz" (occupational safety). In 1919 and the following years, the Ernst-Ludwig-Society of TU Darmstadt Friends supported the installation of the Psychotechnik-Institut. 1921, a teaching assignment was arranged with Erwin Bramesfeld.

In 1922, with the institute's establishment, Bramesfeld defined the scope of the area as:

> "Psychotechnik is the science of the right psychological and economical, thus functional, utilization of the human personality in commercial contexts." (translation by Joachim Vogt)

The TU Darmstadt psychology curriculum today is again focused on work, technology, and organization. Very close to Bramesfeld (Fig. 1), it considers work and humans, products and humans, as well as Betriebe (organizations) and humans.

1925 the university promoted Bramesfeld to the director of the institute (Landau 2013). 1926 he published the textbook "Psychotechnik—Lehrfach an der Technischen Hochschule zu Darmstadt" (Fig. 1). 1930 Bramesfeld became an adjunct professor. The increasingly Nazi-dominated management of Darmstadt University, however, closed the institute due to his refusal of "Gleichschaltung"; it is surprising that Bramesfeld so far succeeded in keeping out Nazi intentions; his figure, for example, did not at all consider warfare (although in the book's text "Kriegstauglichkeit" and other warfare applications are discussed). Under the Nazi terror regime, Bramesfeld left due to political and career reasons—he did not see a future in terms of a permanent chair (Hanel 2014). He was not appreciated by the "working front" (Arbeitsfront). Moreover, he had no permanent contract as a government employee (Beamter). Therefore, he changed his job to the pharmaceutical company Böhringer Ingelheim. The institute, i.e. all equipment, was stored and during the Second World War destroyed.

During the Second World War, Industry 3.0 introduced the first functional computer Z3 by Konrad Ernst Otto Zuse in 1941. The computer was a completely different tool than everything used before. Like the production line, it forced humans to completely conform with the requirements of new and unnatural acts. This continued in Industry 4.0 with the fully atomized productions, supply chains, and mobility processes in the IoT "Internet of Things", for example, smart homes with their privacy, safety, and security problems (Zimmermann et al. 2019). The youngest cycle, Industry 5.0, currently develops increasingly effective and satisfying direct human-robot-interactions. Moreover, artificial intelligence, machine learning, big data, digitalization, and the internet of things are characteristics of Industry 5.0 (Vogt 2021).

In the early 1960s, Bramesfeld became a referee in the re-opening of the institute and evaluated Walter Rohmert as his successor. Rohmert founded the Ergonomics Institute (IAD, Institut für Arbeitswissenschaft Darmstadt). It was

the second institute of this kind in Germany after the sister institute in Aachen, est. 1953. Internationally renowned research and norms originated from IAD like, for example, ISO 10075 about psychological stress and strain. The underlying concept of Belastung (stress) and Beanspruchung (strain) was first published in the early 1970ies after studying among others air traffic controllers ATCos at work (Rohmert and Rutenfranz 1972). ATCos are exposed to stress factors like, for example, the number of aircraft under control and potential conflicts in the traffic flow. The individual ATCo's strain manifests, for example, in heart rate and blood pressure responses (Vogt et al. 2006). The following subchapter will provide more details on the stress and strain research as a prime example for Technikpsychologie in the pharmaceutical industry.

1.2 Psychological stress and strain as an example for Technikpsychologie

Psychological stress and strain play important roles since the beginning of industrialization. Especially in Darmstadt, Rohmert and his co-workers studied job stress and strain (German: Belastung und Beanspruchung) over decades. In the beginning, the research focused on the physical demands of work. Later, in the 1990s, work-psychologists extended the concept by adding psychological stress and strain to the discussion. Their real impact has only recently been recognized, when German law obligated employers to monitor mental stress and strain at work. Nowadays, the monitoring of psychological stress and strain is mandatory in Germany, and, in theory, every workplace in Germany must be analysed according to psychological stress factors. Psychological stress and strain are part of the regular risk-analysis (Gefährdungsanalyse). In the following, an example is given from the pharmaceutical industry.

The chemical and pharmaceutical industry is leading in occupational safety and health. For this reason, psychological stress and strain have been a subject with EH&S-(environmental health and safety) professionals in the chemical and pharmaceutical industry in Germany since very early on.

One outcome of the research is the construction of several scales for the monitoring of psychological stress and strain. Most of these methods are subjective ratings of stress factors and the associated strain reported by workers. For practical issues, there remains a great uncertainty on how to evaluate the findings of these investigations. What amount of stress can be burdened on the worker and what is "too much"? What can be done about strain without violating individual rights (e.g. diet)? In psychological tests, we have norms to evaluate the extent to which a test-score is high or low in comparison to a standard sample. Norms like these are seldom found in the area of psychological stress and strain. In the study that is presented below, we had the chance to analyse a great amount of existing data from a pharmaceutical company (Boehringer Ingelheim) on psychological stress and strain and to produce detailed norms for the ratings to improve the interpretation of the results. Furthermore, we analysed the data according to assumptions developed in cooperation with EH&S-professionals of the company.

1.3 Case study: stress and strain measurement at Boehringer Ingelheim

In the years 2016 to 2019, the company Boehringer Ingelheim cooperated with a business consultancy (Integion) to assess the psychological stress and strain of their employees using an online questionnaire, which was developed by Integion in cooperation with Boehringer. The results were reported back per department and worked on in workshops, to gain a deeper understanding of the situations causing stress and to derive appropriate measures.

As a part of this assessment, 7186 surveys were taken from 149 departments. Boehringer was interested in a collective analysis of this large amount of data, which led to the research cooperation "Gefährdungsbeurteilung psychischer Belastung" between Boehringer Ingelheim and the TU Darmstadt, specifically the Work and Engineering Psychology Research Group (Forschungsgruppe Arbeits- und Ingenieurpsychologie; Keil et al. 2022).

The questionnaire psyGB® consists of 27 items which are each rated twice on four-point-Likert scales. In the first rating, the statements (e.g. "My activities at work are varied") are rated according to psychological stress ("To what extent do you agree or disagree with the following statements?"). The second rating refers to psychological strain ("To what extent do you feel stressed by this?"). The response options for consenting the psychological stress item are "agree strongly", "agree somewhat", "disagree somewhat" and "disagree strongly". Psychological strain is rated "not at all", "not severely", "fairly severely" and "severely". The questionnaire exists in an English and a German version. The items are grouped into four scales:

- Work content/work task (Arbeitsinhalt/Arbeitsaufgabe)
- Organization of work (Arbeitsorganistaion)
- Social relations (Soziale Beziehungen)
- Working environment (Arbeitsumgebung)

Item 27 is an overall-rating of psychological strain ("On the whole, to what extent do you feel psychologically stressed by your work?").

In our investigation we executed several analyses. We performed a content analysis of hypotheses that were generated by experts at Boehringer Ingelheim in a workshop. We analysed differences in stress and strain between the

different departments of the company. We standardized the questionnaire, meaning, we generated statistically supported standards to better compare single mean-values to the whole sample. Furthermore, we compared subjects from three shift models in regards to psychological stress and strain and we revised the survey (psyGB®) to evaluate the suitability as a screening tool.

In July 2020 relevant hypotheses and questions were generated with stakeholders of the project in an online workshop. Based on the structure of the survey psyGB®, potential relations and differences were discussed. From this, possibilities for statistically testable hypotheses were derived.

The analysis of the hypotheses derived from practical experience does not lead to a conclusion that can be summed up in one sentence. However, a nuanced picture of the connections in the survey data can be obtained.

Important positive influences on the relative absence of strain are:

- break and rest times
- good communication
- good social support
- good professional support
- good qualification

Important negative influences on the absence of strain are:

- high work intensity
- high number of disturbances

This allows the deduction of measures for optimizing experienced strain.

A big problem in judging psychological stress and strain is that values are obtained through questionnaires, that cannot specifically be classified as high or low, positive or worrying. To combat this problem, Integion used a traffic light system, the empirical basis of which, however, is unclear. One way of better interpreting values of individuals in organizational units is to form standardizations. Such standards are well known for psychological performance and personality assessments, they are dearly missing for psychological stress and strain.

Using a standardization value, the position of an individual value in the overall distribution of values can be localized. In our investigation, we used percentile ranks to accomplish this.

Another way of dealing with this problem has been proposed by Ferreira and Vogt (2021) by trying to develop threshold values of mental load, based on a categorical system of psychological stress factors.

As no biographic data was obtained in the present data, standardizations were divided by the three major work units "office", "laboratory", and "production". This way, work units with high or low scores in stress and strain can be identified. These are then listed and can lead to further steps taken by professionals on site.

In the separate standards-booklet, the standardization tables are presented for Boehringer Ingelheim overall, office, laboratory, and production.

The questionnaire was analysed according to item difficulty, discriminating power, item wording, and design of the answer-scale. Recommendations for the revision of the questionnaire were derived.

Our investigation has led to an optimized questionnaire, several insights into relations of relevant indicators of psychological stress and strain and to better possibilities of interpretation of stress and strain values. We are looking forward to an optimized risk analysis in the company involved and to a better acceptance of the process of psychological risk-management.

1.4 Outlook and acknowledgements

The concept of mental stress and strain (psychische Belastung und Beanspruchung) is only one, albeit the most prominent and wide-spread (ISO10075 n.d.) example of interdisciplinary human-centred research and development. The following articles provide more of such state-of-the-art research and development examples in Industries 4.0 and 5.0. They bear witness of manifold applications of Technikpsychologie.

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