



Historical paper

“The world is upside down” – The Innsbruck Goggle Experiments of Theodor Erismann (1883–1961) and Ivo Kohler (1915–1985)

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ABSTRACT

The “Innsbruck Goggle Experiments” on long-term wearing of reversing mirrors, prismatic and half prismatic goggles, and colored half goggles represent a milestone in research on *adaptation* (adapting to the introduced “disturbance”) and *after-effects* (after removal of the “disturbance”). By means of these goggles it is, for example, possible to invert or distort the visual field (such as flipping top and bottom or left and right), as well as to observe how individuals learn to change the image back to vertical or recognize left and right. The Innsbruck Experiments gave decisive momentum to further international research on the ontogenetic development of perception, special perception, color perception, perceptual constancy, sensorimotor coordination, as well as to the development of theories. In the current paper, aside from presenting the history and results of selected studies, we will give an introduction to the life and work of the protagonists of these studies in Innsbruck, namely Theodor Erismann (1883–1961) and Ivo Kohler (1915–1985). Furthermore, we will propose ideas for future research on cognition and neuroscience.

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1. Introduction

The famous “Innsbruck Goggle Experiments” were set off by a question that had been posed by the philosopher Oscar Kraus (1872–1942) from Prague: Does whatever you see by nature

have to be “in front” of you? “By means of mirrors, it is easy to invert front and back, and then to observe whether in a longer-lasting experiment objects that are actually behind you will tenaciously be seen ‘in front’ of you – or whether your perception will adjust” (Kohler, 1953a, p. 181).¹ Theodor Erismann and his colleague Hubert Rohracher (1903–1972)

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studied this question by means of a retroscope (a mirror system for reversing images), which inverts “front” and “back”. They presented their first results in 1931, under the title “‘Seeing with the back of your head’ and orientation in a world seen from that perspective” (Rohracher, 1932a). Studies on seeing “upside down” with reversing spectacles, however, received more attention in public, as did studies involving prism spectacles and colored spectacles and their effects, such as apparent movements, color distortions, and after-effects when the spectacles had been removed. Two protagonists, namely Theodor Erismann and Ivo Kohler, are rightly seen as pioneers and designers of the Innsbruck Goggle Experiments; their experiments in the field of psychology of perception received wide recognition.

The first researcher, however, who brought forth the idea to investigate the adaptation of the perception system after retinal images had been artificially and systematically changed (i.e., by “disturbing” the perception), was George M. Stratton (1865–1957) from the University of California at Berkeley (1896, 1897a, 1897b, 1899; see also Stern, 1898; Carr, 1935). He composed optical lenses in a short pipe in such a way that they would put the retinal image upright when placed in front of the eyes. Thus, the first ever reversing spectacles had been created. Stratton’s result of experimenting with these spectacles was twofold: It concerned *external behavior* (failure of grabbing objects, walking, evading, etc.) and *vision* (tables, chairs, the own feet would “hang in the air”, feet would walk on the “ceiling”, taps would drip “upwards”, candle flames would point “downwards”, etc.). In the end of the experiment, there were – despite of the reversing spectacles – moments of upright vision; and after removing the spectacles, there was again the impression of everything “being topsy-turvy”. After 87 h of using reversing spectacles, Stratton proposed that an upside-down retinal image is not necessary for upright vision. The brain would create a coherence in the reversed image between what a person is seeing, hearing, and feeling. The adjustment of seeing, in his opinion, remained just an illusion (see also Ewert, 1936; Stagner & Karwowski, 1952). Although his self-experiments lasted seven days (he wore eye patches at night), these studies were incomplete. The reversing spectacles only allowed for a small visual field and monocular vision. Furthermore, the reversed image also inverted right and left, making the experiment even more difficult. Nevertheless, Stratton’s study can be seen as a starting point for a series of important studies. In these, a variety of image modifications (stimulus transformations) were implemented by selecting and constructing suitable optical systems, and their effects on human and animal perception were investigated. The early studies by Brown (1928), Ewert (1930, 1936, 1937), Gibson (1933, 1937), Peterson and Peterson (1938), Krüger (1939), and Foley (1940), which emerged independently from the Innsbruck group, are worth mentioning. In sum – even if a minority of the findings are contradictory – these results point to the following conclusion: If two different sensory signals are conflicting constantly for a longer period of time, the brain will adapt to this conflict.

In the following section, we will introduce the strained biographies of the Innsbruck Goggle Experimenters, Erismann (Fig. 1), and Kohler (Fig. 2).

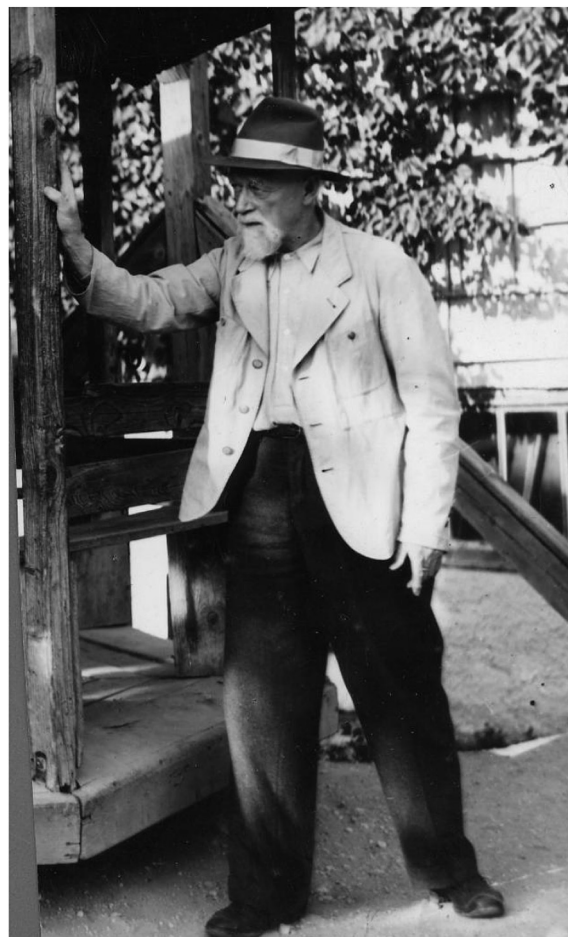


Fig. 1 – Theodor Erismann.

2. Biography

2.1. Theodor Erismann (1883–1961)

Erismann was born on September 16, 1883, in Moscow. His Swiss father, Friedrich Erismann (1842–1915), worked in Russia for a quarter-century as an ophthalmologist, hygienist, and community physician. In 1881, he received an honorary doctoral degree of the University of Moscow, in 1884, he became an Ordinarius for Hygiene. From 1891 he was the director of the Department of Hygiene, and in 1894 he was president of the society of Russian medical doctors. In Zurich, he was university professor and chairman of the municipal health service (see also Rogger & Bankowski, 2010). Theodor Erismann’s Russian mother Sophia Jakowlewna Erismann, born Hasse (1847–1925), was one of the first women in Switzerland to take a doctoral degree in Medicine (University of Bern, July 4, 1876). Because of his connections to and support of liberal, anti-czarist, and revolutionary students, Friedrich Erismann lost his position at the University of Moscow, thus being forced to leave Russia in 1896 and to emigrate to Switzerland. Subsequently (1896–1902), Theodor Erismann attended secondary school (*Realgymnasium*) in Zurich and enrolled at the University of Zurich in 1902. He studied with experimental physicist Alfred Kleiner (1849–1916) and the



Fig. 2 – Ivo Kohler.

latter's then doctorate student, Albert Einstein² (1879–1955), and conducted an experimental study on “the question of the dependency of gravitation on the intermedium” (Erismann, 1908), which was explicitly praised by Einstein. Influenced by Wilhelm Wundt's student Gustav Störing (1860–1946),³ Erismann turned to physiological psychology. “The physicist recognized the exceptionality of psychology, and the psychologist recognized that the soul has a ‘fundamentum in re’ and thus must include natural science” (Kohler, 1984, p. 339). He completed his dissertation in experimental psychology, entitled “Investigation of Movement Perception During Flexion of the Right Arm in the Cubital Joint” (orig. “Untersuchung über die Bewegungsempfindungen beim Beugen des rechten Armes im Ellbogengelenk”, Erismann, 1912), at the University of Zurich with highest honors (“*summa cum laude*”). Still in the same year, he followed Gustav Störing to Strasbourg and habilitated on December 14, 1912, in Philosophy including Psychology (Topic: “Investigation on the Substrate of Movement Perception and the Dependency of Subjective Movement Size on the

² In the Albert Einstein Archive at Hebrew University of Jerusalem, an exchange of letters is documented for the year 1951 (Archival call number: 9–254, 9–254.1, 9–255). A central point within the thought exchange is the publication “Probability in being and thinking. Short presentation of a probability theory and its validity in nature” (orig. “Wahrscheinlichkeit im Sein und Denken. Kurze Darstellung einer Wahrscheinlichkeitstheorie mit Nachweis ihrer Geltung im Naturgeschehen”) by Erismann (1951) on the problem of the justification of inductive thinking.

³ In the journal *Cortex*, Gustav Störing was honored in 2014 by a contribution of Craver, Graham, & Rosenbaum (2014), titled “Remembering Mr. B.” (pp. 153–184).

State of the Muscular System” [orig. “Untersuchung über das Substrat der Bewegungsempfindungen und die Abhängigkeit der subjektiven Bewegungsgröße vom Zustand der Muskulatur”], published in Erismann, 1913). In August 1913, Erismann married Vera Stepanow (1883–1955), a fellow Russian who held a doctoral degree in Philosophy and History of Arts.

Since Erismann did not want to forgo the collaboration with his highly appreciated teacher Störing, he moved in 1914 with him to the University of Bonn, where Störing had accepted an offer for a professorship in Philosophy and Psychology. In 1921, Erismann was appointed adjunct professor. “He was placed first and second on the list of candidates for the professorships of Psychology and Education at the Universities of Bern (1922) and Dresden (1923), respectively” (UAI Ph 2295, 1925/1926). During his time in Bonn, Erismann turned to questions of applied psychology both in teaching and research, particularly the topic of psychotechnique. In 1926 he received an offer to take over the chair of Philosophy and head of the associated Department for Experimental Psychology at the University of Innsbruck; Erismann was regarded as the desired and worthy representative of the institutional unit of philosophy and psychology. Hence, he succeeded Franz Hillebrand (1863–1926), who had founded the Innsbruck Department of Psychology (1897). Erismann remained in this position until he retired on September 30, 1954. “Just as he had never fallen for ‘positions’ or ‘schools’, he never found any of those himself, except for a ‘school’ of responsible and proper scientific thinking” (Kohler, 1953a, p. 182). His focus of work at the department for almost three decades was in the area of empirical-experimental psychological research and the area of philosophy (epistemology, ontology). He was a corresponding member of the Austrian Academy of Science (*Österreichische Akademie der Wissenschaften*) and an honorary member of the German Society of Psychology (*Deutsche Gesellschaft für Psychologie, DGPs*). Erismann died on December 2, 1961, in Innsbruck (for a biographical note on Erismann see also UAI Personalakt Theodor Erismann; UAI Nachlass Theodor Erismann; Goller, 1989; Goller & Tidl, 2012; Kohler, 1953a, 1962a, 1962b, 1984; Windischer, 1953; Strohal, 1962; Stock, 2015).

A note on the man Erismann and the humane attitude in challenging times he represented: In the Halsmann affair (1928–1930), which at that time had attracted attention in whole Europe, the Jewish student Philipp Halsmann was accused of murdering his father during a mountain tour in Tyrol. The process in Innsbruck was characterized by anti-Semitic campaigns. Among others, Erismann protested against the unlawful conviction of Halsmann and wrote an assessment in support of him⁴ (cf. Erismann, 1932; Pollack, 2002).

During the epoch of National Socialism in Austria (1938–1945), Erismann had not been influenced by the ruling doctrine – neither in teaching nor in research. He supported colleagues who had been dismissed (e.g., Richard Strohal [1888–1976]). From 1938, among other actions, he was defamed as “partly Jewish” (Goller & Tidl, 2012, p. 51/52). After his public,

⁴ Four university professors from Innsbruck formulated together an objection to the department of public prosecution and explicitly spoke about a false judgment: Theodor Erismann (psychology), Alfred Kastil (philosophy), Theodor Rittler (penal law), and Ferdinand Kogler (German law; cf. Pessler, 1931, p. 48f.).

anti national socialistic talk “Mass Psychosis and the Individual” (orig. “Massenpsychose und Individuum”, February 16, 1944), he received a severe warning by Dean Otto Steinböck (1893–1969),⁵ was dismissed from his position of director of the Philosophy and Education Seminar, and excluded from exam committees and from university events. In 1945, Erismann was involved in the abolition of the national socialistic university administration. However, after the liberation, he took over the position as dean of the Philosophic faculty and even founded a relief fund for the colleagues who had been dismissed within the scope of denazification ... “He seemed to be invariably blowing against the wind” (Kohler, 1962a, p. 175).

2.2. Ivo Kohler (1915–1985)

Kohler was born on July 27, 1915, in Schruns, Vorarlberg (Austria). He was the oldest son of Dr. Sebastian Kohler (lawyer in Vienna) and Elsa Kohler, née Hefel. Ivo Kohler attended primary school in Vienna, followed by the grammar school (*Gymnasium*) “Stella Matutina” (Jesuit college) in Feldkirch. He graduated from high school in 1934 (“Matura”) with distinction. His time at school, however, was interrupted by attending at a metalworking school in Fulpmes (Tyrol). From 1934, he studied theology and scholastic philosophy at the episcopal seminary in Brixen (Southern Tyrol); he continued these studies from 1937 at the Faculty of Philosophy at the University of Innsbruck. Although he was drafted from the Wehrmacht already in March 1940, he was able to obtain his doctorate with Erismann during a granted study leave as early as in April 1941 on the topic “The influence of experience in optical perception, illuminated by experiments of long-term wearing of image distorting prisms” (orig. “Der Einfluss der Erfahrung in der optischen Wahrnehmung beleuchtet von Versuchen langdauernden Tragens bildverzerrender Prismen”). His subjects of his accompanying exams were philosophy, psychology and physics.

After the end of World War II, he became an assistant to his teacher Erismann “by special decree”, a position he would be holding for over ten years. In the beginning, Kohler had to face a denazification lawsuit, since he had been a member of the National Socialist German Workers’ Party (NSDAP) from July 1938 and furthermore a member of the Sturmabteilung (SA) from August 1939 (cf. Österreichisches Staatsarchiv, AdR-02-BMU-Pa Kohler). In this lawsuit, which was completed in 1948 (“amnesty for less incriminated”), his advocates from the university were Erismann, who was dean at the time, and Professor Hubert Rohrer, whose scientific career had started at the University of Innsbruck.

On July 21, 1950, Kohler received his ministerial license to teach “psychology with particular consideration of experimental psychology”. His habilitation thesis summarized the

⁵ “Judging by unmistakable phrases, a spirit is revealed to me that seems to be more than disconcerting, and that forces me to consequences. Because you belong to my faculty, I, as a dean, warn you urgently and strongly advise you to refrain from conveying attitudes that you expressed in the talk to your audience at any other opportunity. Should I, as the dean, receive any more notice to this effect, I would have to and would intervene relentlessly. The consequences for you would be disastrous” (Letter from February 29, 1944, by the dean Otto Steinböck to Theodor Erismann [UAI Personalakt Theodor Erismann]).

results of the longstanding Innsbruck research on long-term wearing of spectacles with mirrors, prisms, half prisms, and colored halves. Using such artificial means, he created “disturbances” (vertical and lateral inversion, image distortion, etc.) and directly interfered with the organization of perception, observed the course of these “disturbances”, or more specifically, the progress of the adaptation period, discussing the important question as to how perception processes form and sustain their organization by means of their own correction processes, and which factors are important in this respect. For the first time, Erismann’s “method of systematic disturbance” was comprehensively applied with the aim of analyzing the organization of the perception domain by means of its own correction processes (Kohler’s habilitation thesis is entitled “On the composition and transition of the world of perception” [orig. “Über Aufbau und Wandlungen der Wahrnehmungswelt”]; Fig. 3). Besides an orientation towards basic and experimental research, a further focus of Kohler’s work was in the domain of applied investigations, for example on the performance of blind individuals in orientation and their support by means of technical artifacts. Upon request by Kohler in January 1953, his *venia legendi* was expanded to philosophy. In spring 1956, he was named adjunct professor of psychology, and as such became Erismann’s successor as director of the Department of Psychology. He held this position until 1980. What contributed substantially to Kohler’s appointment in Innsbruck were glowing letters of reference on his excellence, written by George M. Stratton (University of California, Berkeley), James J. Gibson (1904–1979, Cornell University, Ithaca), Egon Brunswik (1903–1955, University of California, Berkeley), Wolfgang Metzger (1899–1979, University of Münster), and Heinrich Düker (1898–1986, University of Marburg), amongst others. “It is out of question that in the whole German-speaking field of psychology, there is no more suitable and qualified person than Dr. K. [i.e., Kohler] who could continue to pursue the perception psychological tradition, founded by Hillebrand and Erismann, at the Department of Psychology in Innsbruck” (UAI Personalakt Theodor Erismann, see also Österreichisches Staatsarchiv, AdR-02-BMU Pa Kohler).

In 1960, Kohler married his colleague Dr. Erika Merker. Research leave and guest professorships brought Kohler to Duke University at Durham (1960), to the Center for Advanced Study in the Behavioral Sciences at Stanford (1962/1963), to Cornell University at Ithaca (1963), to the University of Vermont at Burlington (1969/1970) and to University of Kansas at Lawrence (1973). Kohler became professor emeritus in 1981 and died on January 23, 1985, in Innsbruck (on the biographical note Kohler, cf. UAI Personalakt Ivo Kohler; Hajos & Ritter, 1984, 1988; Hajos, 1985; Ritter, 1986; Bouwhuis & Owens, 1986; Lücke & Pfister, 1988; Forgy & Lawson, 1989; Allesch, 2015). Kohler was a passionate, unconventional, extraordinarily original,⁶ creative and imaginative researcher. He lived

⁶ A scientific joke: Kohler added a note in mirror writing to the book “Dichotomy and Duplicity: Basic Questions of Psychological Insight – In Memory of Ernst August Dölle (orig. *Dichotomie und Duplizität: Grundfragen psychologischer Erkenntnis – Ernst August Dölle zum Gedächtnis*)” (Huber-Verlag, Bern, 1974). It should be added: Ernst August Dölle never existed ... This scientific joke is one example among many.

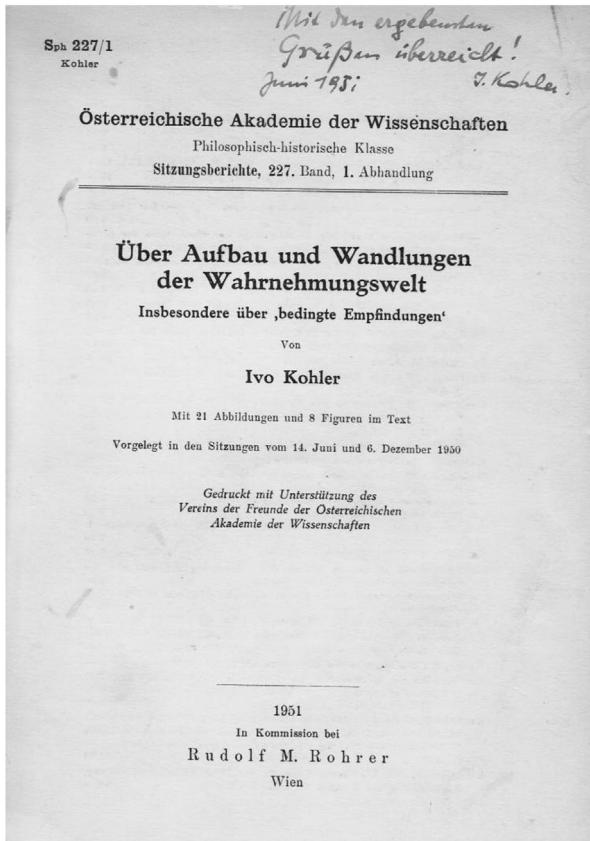


Fig. 3 – Dedication copy of Kohler's habilitation thesis “On the composition and transition of the world of perception” from June 1951 (Private property of the first author).

– like Erismann – the scientific principle of the Innsbruck department at that time: “unlimited tolerance and respect towards each and every opinion” (Hajos & Ritter, 1988, p. 20).

3. The Innsbruck Goggle Experiments

Extraordinary enthusiasm, persistence, and experimental expertise were needed in order to conduct the goggle experiments, which lasted for weeks and sometimes months and were at the limit of what is possible for the participants as well as for the experimenter. After the first publications from the Innsbruck department related to the topic (Rohracher, 1932a, 1932b; Schüler, 1933), it was Erismann himself who wore a pair of prism spectacles in an experiment that lasted for three weeks (September/October 1933). In the experimental protocol of September 24th, 1933, he noted:

“I put on the glasses at around 9 am this morning. The most notable impressions while moving the body are by all means the movements within the visual field. In comparison with them, even the curvatures fade into the background. Presently, they appear to be less – or even minimally – observed. The impression of movement that was so very intrusive in the beginning may already have decreased somewhat. Furthermore, changes in the shape of objects catch one's eye. Walls change to rhombs and rhomboids; accordingly, the sheets of paper [change], books, tables, if seen from above; a cup

becomes elliptic, etc. ... Of course the corners of the room are overly blunt or pointed, depending on the position of the head ... During a walk, my steps shook a bit only a few times, and I lost the confidence in my balance maybe once, otherwise, the texture of the floor is hardly bothersome ... Closer objects seem to be curved to a stronger and more pronounced degree than objects further away – even in the same angular segment.” He finishes the protocol of the same day with the following statement: “I am in a fairly stable world now, even if the images change. But my relation to the world is constant and secure” (Kohler, 1941, p. 149).

His student Kohler published Erismann's entire self-experiment – besides prism spectacle experiments performed by Franz Schüler, Heinz Miller, and himself – in his dissertation, which appeared in 1941. In Erismann's opinion, a significant result of the first series of studies involving prism spectacles was the lack of absolute optical spatial values and that the retina alone can't determine the absolute position of the visual field. For the formation of the top/bottom localization, gravity plays an important role. Kohler discussed problems in spatial perception firstly in the light of the “Local Sign Theory” by Rudolf Hermann Lotze (1852) and Wilhelm Wundt (1874). The term “Local Sign” refers to perceptions that help to build a spatial order (spatial vision etc.). As a result of the Innsbruck Goggle Experiments, this theory was extended to the effect “that such local signs in any case are not unmodifiably fixed, but adjust according to new situations” (Pongratz, 1984, p. 90). Kohler located empirical results on color phenomena while wearing prism or colored spectacles in the physiological (and psychological) “Theory of Opponent Colors” by Ewald Hering (1875). Later on, Kohler was particularly close to the ecological theory of perception by James J. Gibson (1961, 1979).

Typically, the goggle experiments (Fig. 4) resulted in a process with three characteristic phases (cf. Kohler, 1951b)⁷:

- Between the first and third day, the world was upside down for the participant. There were many mistakes in grabbing objects and moving. For instance, the participant held a cup upside down when it was about to be filled; or they stepped over a ceiling lamp or street sign, because they saw objects at the bottom that were actually at the top. Swift reactions (such as parrying an attack off during fencing) happened uncorrected, and thus in the wrong direction.
- By the fifth day, the participant's clumsiness in external behavior and vision started to change. Things that had been seen upside down suddenly were upright once the participant brought their own hands in and traced the shapes they saw with their hands. Or, phrased differently: If the participant “viewed the world using their fingers”, then it turned upright in their vision as well, an immense effort of the brain. By grasping, the perception changes.
- From the sixth day of uninterruptedly wearing reversing spectacles, permanent upright vision ensued, and behavior

⁷ The experiments' most important phases were also presented in the scientific movies “Upright vision through inverting glasses” (orig. “Die Umkehrbrille und das aufrechte Sehen”; 1950) and “Living in a reversed world” (orig. “Verkehrte Welten”; 1954) by Pacher & Co.

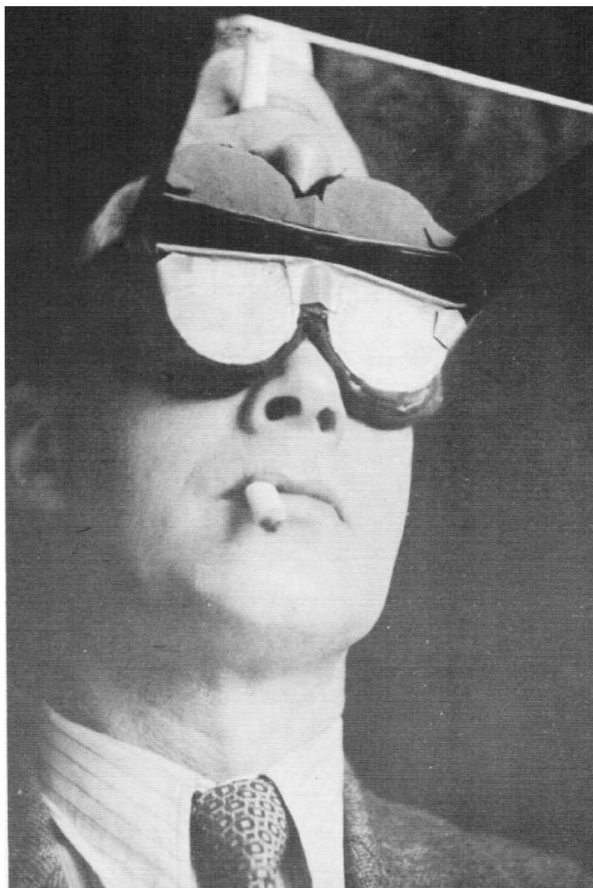


Fig. 4 – Reversing spectacles by Erismann from 1947; a metal mirror enables reversing beams concerning top-bottom orientation.

was perfectly correct. For example, a participant drew a picture in a quality as if drawn without wearing reversing spectacles.

After taking off the glasses, however, participants saw the whole world upside down, a distortion “in the opposite direction” (negative after-effect), but the reversed vision only lasted a few minutes.

“The top-bottom perspectives of vision only emerge in constant interaction with experiences of the other senses (particularly the tactile sense and muscle sense). Therefore, the position of the retinal image in the background of the eye is only significant as long as older experiences from the past continue to have an effect. In the experiment, they are reduced step by step and are, via a stage of ‘ambiguous top-bottom perspective’, connected in a new way with the new visual impressions” (Kohler, 1951b, p. 33). The studies show that first, movement behavior returns to normal, and only then is followed by perception. Successful adaptations to a changed world of perception require a person’s active exploration of and interaction with their environment (Hommel & Nattkemper, 2011; Kohler, 1951b).

It was always due to Erismann’s initiative, verve, experience, and scientific curiosity that more and more students and

associates were ready to help with new long-term studies with those special goggles, committing themselves for weeks or even months. (For example, Kohler wore binocular reversing spectacles for 24 h a day over a period of 124 days from November 1946 until March 1947; this was probably unique within psychological research, cf. Kohler, 1951a, 1964).

The Innsbruck Goggle Experiments were progressive also in terms of their methodology. By means of the long-term studies, the Innsbruck department left the lab and investigated various processes and effects in the realm of perception psychology in the field, that is, under ecologically valid conditions. Various activities, such as watching a movie or a circus performance, going to a tavern, after a few days even bike, motor bike, and going on ski tours, were naturally part of the studies of the goggle-wearing participants (Figs. 5 and 6). Part of the results were not only subjective data from self-observation and peer-observation, but also data from quantitative measures of adaptation performance in everyday life.

Because of World War II, important results of the Innsbruck Goggle Experiments on the topic of “Emergent Perception” – which was the title of a presentation of Erismann 1947 in Bonn (orig. “Werden der Wahrnehmung”; additionally published as a conference report of the Society of German Psychologists, DGPs) – could only be published with a delay. In 1948, at the XII. International Congress of Psychology in Edinburgh, Kohler had the opportunity to open up research contacts to the English-speaking field of psychology (cf. Kohler, 1950). The publication of Kohler’s habilitation thesis “On the composition and transition of the world of perception” (1951a; orig. “Über Aufbau und Wandlungen der



Fig. 5 – Participant with prismatic goggles (top/bottom) in Innsbruck (Austria).



Fig. 6 – Participant on day 32 of wearing prismatic goggles (left-right).

Wahrnehmungswelt“) was a scientific milestone. It bundled the significant results of the Innsbruck Goggle Experiments across two decades and reflected them in a congenial way. The monography – as one of only a few at that time – was translated into English with the title “The Formation and Transformation of the Perceptual World” (Psychological Issues/Monograph, 1964), which was substantially promoted by James J. Gibson of Cornell University. The planned and lasting “disturbance” of perception should supposedly also contribute to the clarification of normal developmental laws of perception. The concept was successful and elicited several replication and follow-up studies (such as on perceptual learning) in Anglo-Saxon countries (e.g., Dolezal, 1982; Epstein, 1967; Harris, 1965; Rock, 1966; Smith & Smith, 1962; Snyder & Pronko, 1952; Taylor, 1962; Welch, 1974, 1978) and in Japan (Shigeoka, 1961; Makino, 1963; Tashiro, 1970, among others). At the department in Innsbruck, research on specific problems of perception with prismatic spectacles were also continued, as documented in publications by Erismann (1950), Kohler (1951b, 1953b, 1955, 1956, 1962c, 1974), Kottenhoff (1957a, 1957b, 1961), Pissarek (1958), Hinteregger (1959), Kohler and Pissarek (1960), and Thurner (1961, 1967). The commemorative publication for Kohler, “Sensory experience, adaptation, and perception” (edited by Spillmann & Wooten, 1984), can be seen as the end of the classic Innsbruck Goggle Experiments.

The original studies with prisms prompted a number of researchers to replicate the original works and investigate the underlying cognitive and neural processes of visuomotor learning and adaptation (Clower et al., 1996; Linden, Kallenbach, Heinecke, Singer, & Goebel, 1999; Tanaka, Miyauchi, Misaki, & Tashiro, 2007). These studies revealed that visuomotor skills recovered to near-baseline levels after long term adaptation to inverting or reversing goggles of several days or even weeks (Degenaar, 2014; Lillicrap et al., 2013; Miyauchi et al., 2004). The adaptive processes involve

(i) various brain areas, including parietocerebellar networks, temporal lobe and visual cortex as well as frontal areas like the anterior cingulate cortex (e.g., Baldassarre, Capotosto, Committeri, & Corbetta, 2016; Danckert, Ferber, & Goodale, 2008), and (ii) various neural signals, such as the error-related negativity and P300 (MacLean, Hassall, Ishigami, Krigolson, & Eskes, 2015). Thereby, the adaptation process seems to involve multiple phases and changes in neural signals and brain areas (Lillicrap et al., 2013; MacLean et al., 2015; Sekiyama, Hashimoto, & Sugita, 2012). Additionally, it was found that prism adaptation stimulated neural plasticity to reversed retinal input in that a transfer of neuronal (V1) activities to the opposite visual cortex took place (Sugita, 1996). A further finding was that visuomotor adaptation to reversed visual input was predicted by brain-derived neurotrophic factor Val⁶⁶Met polymorphism (Barton et al., 2014).

4. Conclusion

Under the aegis of Erismann and Kohler, researchers at the University of Innsbruck conducted groundbreaking experiments on prismatic spectacles, which present an important methodological paradigm in psychology of perception. By means of such glasses, the visual field can be reversed or distorted (e.g., switching top and bottom, or left and right), and it can be observed how participants learn to readjust the visual field back into a vertical perspective and to recognize left and right. Usually, in these studies one can find *adaptation* (adjustment towards the introduced changes – the “disturbances”). As soon as these “disturbances” are removed, typically an opposing “*after-effect*” occurs, called “*situational after-effect*” by Erismann (1948, p. 54) and “*conditioned sensations*” by Kohler (1951a, p. 10).

Starting point for the Innsbruck Goggle Experiments was a central problem of psychology of perception, namely the relation of stimulus structure and perception. Furthermore, the goggle experiments affected the basic problem of inter-sensory coordination, the “*choreography*” of the different senses, so to say, as well as the already mentioned problem of adaptation. Moreover, the studies pointed towards the significance of feedback and feedback distortion when seeing movement.

The Innsbruck Goggle Experiments gave internationally verifiable crucial indications on the research on ontogenetic development, perception constancy, sensorimotor coordination, as well as on theoretical developments in the area of perception psychology. They have a lasting impact on perception psychology research up to the present day (cf. Bedford, 1993; Held & Hein, 1958; Held, 1965; Howard, 1974; Kornheiser, 1976; Lackner, 1981; Michel, 2016; Redding & Wallace, 1992, 2013; Redding, Rossetti, & Wallace, 2005; Singer, Tretter, & Yinon, 1979; Striemer & Danckert, 2010; Taylor, 1962; Mialian and Held, 1964; Werner & Wapner, 1955).

In summary, the following specific conclusions can be drawn from the Innsbruck Goggle Experiments:

- Human perception proves to be remarkably plastic and adaptive; there is no rigid allocation of environmental stimulus and perception. “Spatial vision, the synergy of

vision and the tactile sense, the perception of shapes etc. change by learning. [...] ‘Intelligent’ processing systems are involved in our perception. They can decode characteristics and features of the environment correctly, even if information assimilation is disturbed” (Ritter, 1986, p. 233, p. 233)

- Perception isn't a passive process of depicting stimuli that flow in from outside, but a product of constructive, active processes (in which simple sensory processes are directly connected with higher ones, such as those of the memory).
- Perception can preserve its own organization by means of correction processes. Feedback on one's motoric actions is an important requisite for these.

Wilhelm von Humboldt's statement “Only who knows the past has a future” self-evidently holds true for the inspection of the research history on perception psychological studies on effects of distorted visual perception. Thus, at the same time it can be applied on a prospective design of future research that goes beyond that field within cognition and neurological research, such as experimentation on (a) adaptation and perceptual learning in multi-modal perception, (b) impact of different cortical processing levels on perceptual learning, (c) dependency of perception on current and prior context, (d) interaction between perception and action, and the coordination of multiple actions and goal-directed action control, and (e) motoric learning.

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ARCHIVAL MATERIALS

UAI – Universitätsarchiv Innsbruck.

- UAI, Akten der Philosophischen Fakultät (=Ph) Nr. 2295 aus 1925/26, Besetzungsvorschlag der Philosophischen Fakultät Innsbruck für die nach dem Ableben Hillebrands erledigte ordentliche Professur vom 1.7.1926.
- UAI, Reihe Personalakten, Karton 51, Personalakt Theodor Erismann.
- UAI, Reihe Personalakten, Karton 116, Personalakt Ivo Kohler.
- UAI, Nachlass Theodor Erismann (1 Karton).

Österreichisches Staatsarchiv, Archiv der Republik.

- AdR-02-BMU-Pa Kohler

The Albert Einstein Archives, The Hebrew University of Jerusalem.

- Archival call number: 9–254, 9–254.1, 9–255 (Briefwechsel zwischen Theodor Erismann und Albert Einstein, 1951)

Scientific movies

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