Störring and Lindworsky: Two Pioneers in the Psychology of Deductive Reasoning

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This paper sheds light on the history of early experimental psychological work on deductive reasoning. We identify Gustav Wilhelm Störring and Johannes Lindworsky as the pioneers of the experimental psychology of deductive logic. After presenting an overview on their life and works, we trace personal and scientific connections to the Würzburg School to help situate them within the scientific community of the 20th century. Our work is intended to present an overview on the life and works of Störring and Lindworsky, focusing on their works on deductive reasoning, to uncover the history of the psychology of reasoning.

Keywords: Gustav Wilhelm Störring · Johannes Lindworsky · history of the psychology of deductive logic · Würzburg School

Introduction

We present research on the German philosophers and psychologists Gustav Wilhelm Störring (1860–1946) and Johannes Lindworsky (1875–1939), who performed pioneering research on human deductive reasoning. After briefly contextualizing their lives and work, our aim is in particular to throw light on their pioneering experimental-psychological research on deductive reasoning. While reasoning is generally conceived as involving higher-order thought processes like problem solving, decision making, or drawing inferences about the world, our focus is on *deductive* reasoning. Deductive reasoning concerns judgments of logical validity, whether conclusions follow necessarily from the premises and its quality is hence evaluated by the standards of formal deductive logic. In this sense, deductive reasoning is concerned with truth-preservation (i.e., if all premises are true, is

the conclusion necessarily true?) and the study of logical form.[1] While the history of the psychology of non-deductive reasoning processes (like problem solving) is fairly well investigated, we give a first overview on the not so well-known history of psychology of deductive reasoning and its relevance to philosophy. We also aim to draw connections from Störring and Lindworsky to the researchers of the Würzburg School. This helps to shed light on the circumstances that shaped their work, and how they also might have shaped others.

The work of Störring and Lindworsky, whose pioneering psychological works on deduction were published at the beginning of the 20th century, is still relevant today: we show that they not only conducted important groundwork for the psychology of deductive reasoning, but also investigated problems of current research interest. Störring and Lindworsky can be seen as precursors to subsequent developments in the psychology of reasoning.

To illustrate why this research is relevant, let us look at Jonathan St B. T. Evans, who begins his "informal history" (2011, 423) of the psychology of reasoning with Wilkins (1928) and Woodworth and Sells (1935).[2] Already two decades earlier, however, Gustav Wilhelm Störring (1908) presented the first experimental psychological paper on deductive

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[1] Gottlob Frege's *Begriffsschrift* (1879), which is known to be the "first really comprehensive system of formal logic" (Kneale & Kneale, 1984, 510), had already been present for two decades before the work of Störring and Lindworsky. However, they were mainly concerned with logic in the sense of syllogistic reasoning, which originated with Aristotle. The *Begriffsschrift* contains the propositional and the predicate calculus, which started to gain popularity among logicians and philosophers after its logic was presented in a more accessible manner by Whitehead and Russell (1910–1913), compared to Frege's non-standard diagrammatic notation. For this reason syllogistic logic was still dominant at the beginning of the 20th century, which explains Störring's and Lindworsky's preferences for this traditional logic (for more on the history of formal logic see, e.g., Kneale & Kneale, 1984).

[2] Indeed, Evans stated that "[t]he first experimental papers on the psychology of reasoning of which I am aware were published before World War II and used categorical syllogisms (Sells, 1936; Wilkins, 1928; Woodworth & Sells, 1935)" (2011, 423).

reasoning. Eight years later, Johannes Lindworsky (1916a) published the first book on this topic. This shows that there is not just the need to recognize their pioneering research, but also to give them a place within the history of psychology and philosophy.

In this paper we focus on the history of psychology: this, as well as providing a basis for future research, is the purpose of the present paper.

The structure of our paper is as follows. In the next section, we provide an overview on the lives and works of Gustav W. Störring and Johannes Lindworsky. Then, we focus on their research in the psychology of deductive reasoning and discuss Störring's and Lindworsky's connections to the Würzburg School to contextualize their work in the history of the psychology of reasoning. We also relate their work to later developments in the field. Finally, we present concluding remarks and point to future research directions.

Gustav Wilhelm Störring and Johannes Lindworsky

The Life and Work of Störring

Gustav Wilhelm Störring was born in Vörde in August 1860 and died in Göttingen in December 1946 (Steinberg & Künstler, 2000, 243). He studied theology, medicine and philosophy in Halle, Berlin, Bonn, and Kiel (Stöwer, 2003, 7 ff.; Steinberg & Künstler, 2000, 243 f.). After his studies, he briefly worked as an assistant doctor at the psychiatric hospital in Hubertusburg near Leipzig (Steinberg & Künstler, 2000, 244). He then worked at the university hospital in Leipzig (Steinberg & Künstler, 2000, 244). In 1897, Störring obtained his doctorate in medicine from the *Königlich Bayerische Julius-Maximilians-Universität* in Würzburg (Stöwer, 2003, 9; see Universitätsarchiv Würzburg, 2025).[3] In 1896, Störring habilitated in philosophy with Wilhelm Wundt (Hauss, 1961, 80) and subsequently taught philosophy and psychology at the *University of Leipzig* until 1902 (Steinberg & Künstler, 2000, 246; see Universität Leipzig, 2025). Among other topics, he taught courses on psychopathology, the history of philosophy, and classical philosophy (Universitätsbibliothek Leipzig, 2008–2020). During that time he published his most important and best known work *Vorlesungen über Psychopathologie in ihrer Bedeutung für die normale Psychologie* (*Lectures on mental pathology in its relation to normal psychology*) (Steinberg & Künstler, 2000, 243, 247; Herrmann, 2006, 21; Boring, 1957 [1929], 429). It contains the first systematic methodology of psychopathology (Steinberg & Künstler, 2000, 243), and was translated, in one case partially translated, into three languages: English, Russian, and Portuguese (1907; 2010; 1903; 2016). Because of Störring's conception that "in pathological cases nature experiments for us" (1900, 11; own translation), Wilhelm Wundt characterized Störring's *Lectures on mental pathology in its relation to normal psychology* as epochal (Fischer, 1940,

[3] According to Antonia Kreibich und Andreas Maercker (2020), who contradict other sources, Störring obtained his doctorate in medicine in 1894 in Berlin.

393).

Parallel to his lectureship in Leipzig, from 1897 until 1902, Störring ran a psychiatric clinic in Erdmannshain near Leipzig together with his wife Marie Störring (Steinberg & Künstler, 2000, 245 ff.). In 1902, Störring became professor for the history of philosophy in Zürich, and in 1910 also for systematic philosophy, pedagogy, and experimental psychology (Kreibich & Maercker, 2020, 397).

It was during his time in Zürich that he published his two pioneering papers in the psychology of reasoning. The first of them, *Experimentelle Untersuchungen über einfache Schlußprozesse*, published in 1908, constitutes the experimental report of the first experiments done in the field of deductive reasoning (Lindworsky, 1916a, v). However, as Lindworsky pointed out eight years after the publication, Störring's results did not make their way into psychology textbooks (1916a, v). In his *Experimentelle und psychopathologische Untersuchungen über das Bewußtsein der Gültigkeit* (*Experimental and psychopathological investigations on the consciousness of validity*, (1909b)), published one year later, Störring also presents experiments on deductive reasoning. Both of those papers will be discussed in more detail below. In 1910, Störring was made the head of the psychological laboratory at the *University Zürich* (Kreibich & Maercker, 2020, 397). He remained professor there until 1911 (Hauss, 1961, 80). From 1911 until 1914, Störring was professor at the *Kaiser-Wilhelms-Universität* in Strasbourg (Hauss, 1961, 80; see Mayer, 1922), and then went to the *Rheinische Friedrich-Wilhelms Universität* in Bonn where he became professor for philosophy and psychology (Völkel, 2010; see Becker, 2025). During his time in Bonn, Störring was committed to the advancement of women in academia: Martha Moers and Maria Schorn, who were the first women to habilitate in psychology at a German university, obtained their doctorates with him (Rudinger, 1999, 43). In 1927, Störring was given the emeritus status (Baumann & Wich-Reif, 2018, 672).[4] After his

[4] Theo Herrmann (2006) and Georg Rudinger (1999) give the same date for Störring's retirement. According to Ralph Stöwer (2003, 14), however, Störring retired in 1928. Yet another source gives 1929 as

retirement, he left Bonn and spent the rest of his life in Berlin, Göttingen, and Bâle (Stöwer, 2003, 17).

Gustav Wilhelm Störring had five children (Wirth, 1940, 386). Four of them worked in similar fields as their father (Wirth, 1940, 387 f.). His eldest son, Ernst Störring, lived from 1898 until 1952 and was professor for medicine (see Solafide, 2016; Wirth, 1940, 387 f.). The second oldest son, Wilhelm Störring, did not merely work in the same field as his father, but also conducted experiments on deductive reasoning, and even adopted the experimental setup his father used in his experiments on deductive reasoning for his own experiments (W. Störring, 1925, 467). Wilhelm Störring mentions that his father had suggested to him to do this research (W. Störring, 1925, 512), and Gustav Wilhelm even writes that he assigned this task to his son Wilhelm (G. W. Störring, 1925, 19). Wilhelm Störring also mentions that someone called "Herr stud. med. Gustav Störring" was among the participants for his experiments (W. Störring, 1925, 512). This was probably his brother, Gustav Ernst Störring, who was studying medicine in Kiel at the time of publication (Auge, Bruhn, & Peterson, 2025). Today, Gustav Ernst is better known than his father Gustav Wilhelm, because of his neurological and psychiatric work (Herrmann, 2006, 20). Gustav Ernst was, together with Störring's son Wilhelm, a participant in the experiments for Störring's 1926 book *Das urteilende und schließende Denken in kausaler Behandlung* (Herrmann, 2006, 21 f.; G. W. Störring, 1926a). Störring's youngest son, Ferdinand Störring, was a medical doctor (Wirth, 1940, 387). Störring's daughter, Gertrud Störring, married the economist Hans Ritschl (Wirth, 1940, 390).

A more philosophical among Störring's works is his 1924 book *Was soll uns Kant sein?* (*What should Kant be to us?*). In this book, Störring talks about Kant's achievements in theoretical, as well as practical philosophy, and attempts to show an alternative route to how synthetic statements *a priori* can be made (1924, 1, 46 ff.). Synthetic statements *a priori* contain knowledge, which is gained solely from reason (*a*

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the year of his retirement (Hauss, 1961, 80).

priori) but which nevertheless state something about the world (synthetic). Störring suggests that in the field of pure thinking synthetic statements *a priori* are made in logical inferences: the conclusion is drawn from a synthesis of the premises (1924, 46 ff.). This is something that also plays a role in his experiments on deductive reasoning.

The Life and Work of Lindworsky

Johannes Lindworsky was born in Frankfurt am Main in January 1875 (Lindworsky, 1916b, 96), and died in September 1939 in Essen (Ühlein, 1986, 39). In 1897, at the age of 22, he joined the Society of Jesus (Lindworsky, 1916b, 96). As part of his training in this congregation he studied philosophy and theology in Valkenburg in the Netherlands (Misiak & Staudt, 1954, 114 f.; Ühlein, 1986, 22). In 1909, he was ordained to priesthood (Ühlein, 1986, 22). Two years later, Lindworsky changed his surname from *Linwurzky* to *Lindworsky* (Keilbach, 1962, 27). As far as can be told, he did not publish any major works under his original surname. In 1911, Lindworsky went to Munich to study psychology and pedagogy at the *Ludwig-Maximilians-Universität* (Lindworsky, 1916b, 96; see Ühlein, 1986, 253 ff.). He stayed there for one year and then continued his studies at the *Rheinische Friedrich-Wilhelms Universität* in Bonn until 1913 (Ühlein, 1986, 24). His teacher in Bonn was Oswald Külpe of the Würzburg School and Külpe's assistant there was Karl Bühler (Ühlein, 1986, 24). Lindworsky started his experiments on deductive reasoning in Bonn, "at the instance of O. KÜLPE", with Bühler participating in his experiments (Ühlein, 1986, 25; own translation).

In 1913, Lindworsky went, together with Külpe and Bühler, back to Munich to the *Ludwig-Maximilians-Universität* to continue his studies (Ühlein, 1986, 25; Misiak & Staudt, 1954, 115). There, he obtained his doctorate with a study on deductive reasoning (Lindworsky, 1916b). His dissertation *Die Gestaltungsweisen des syllogistischen Denkens* (*Forms of Syllogistic Thinking*; 1916b) was published with additional material on natural

reasoning processes in the same year as a book.[5] This book, entitled *Das schlußfolgernde Denken* (*Inferential Thinking/Reasoning;* Lindworsky, 1916a), was the first experimental-psychological book on deductive reasoning to be published.

In 1920, Lindworsky went to the *University of Cologne* (Misiak & Staudt, 1954, 115), where he habilitated in the same year (Wolfradt, Bollmann-Mahecha, & Stock, 2017, 279). He taught at the *University of Cologne* from 1920 to 1928 and became an extraordinary professor in 1923 (Misiak & Staudt, 1954, 115). From 1927 to 1929, Lindworsky also taught summer courses in experimental psychology at the *Gregorian University* in Rome (Ühlein, 1986, 33). Lindworsky became professor of psychology at the *German University* in Prague in 1928 (Misiak & Staudt, 1954, 115). He remained in this position until the spring of 1939, a couple of months before his death in September that year (Ühlein, 1986, 39).

In the present paper we focus on Lindworsky's pioneering experiments on deductive reasoning (Lindworsky, 1916a), which will be discussed in greater detail in the next section of this article. Apart from this, Lindworsky did not conduct any further experiments on reasoning, but did give a talk on the reasoning process of so-called *primitive people* by which he meant indigenous people (Lindworsky, 1926a). At the time, this was a relevant topic in folk psychology (Stubbe, 2019, 44 f.). A few years before that he had already published a similar paper, which dealt with the reasoning process of prehistoric humans (Lindworsky, 1917/1918). Lindworsky also published two methodological papers which, among other things, deal with the method of introspection, which he used in his experiments on reasoning (Lindworsky, 1913, 1925).

Henryk Misiak and Virginia M. Staudt call the following the five major works of Lindworsky (1954, 115): *Der Wille. Seine Erscheinung und seine Beherrschung nach den Ergebnissen der Experimentellen Forschung* (1919), *Experimentelle Psychologie* (1921), *Umrissskizze zu einer Theoretischen Psychologie* (1922), *Willensschule* (1922) and

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[5] The first 95 pages of the book (Lindworsky, 1916a, sections 1 and 2) correspond to the same layaout as the dissertation. Page 96 of the dissertation contains a one page autobiography of Lindworsky.

Psychologie der Aszese: Winke für eine psychologisch richtige Aszese (1935). Of these major works, there are translations in a total of seven languages.[6] In his *Experimental Psychology*, Lindworsky also investigates the apprehension of relations, which was a central theme in his experimental investigations on reasoning (DeSilva, 1931, v f.).

In contrast to Störring's works, Lindworsky's works were better known and received in other countries, albeit, as for Störring, not the pioneering works on deductive reasoning. Those were and are, in both cases, fairly unknown, Störring's 1908 paper was only translated into French about a century after its first publication in German (Jamet & Déret, 2003). As far as can be told, both Störring's *Experimentelle Untersuchungen über einfache Schlußprozesse* from 1908 and Lindworsky's *Das schlußfolgernde Denken* from 1916 only went through one German edition each. According to the Austrian psychologist Hubert Rohracher, Lindworsky was, however, one of the leading German psychologists of his time (1972, 269).

Connections Between Störring and Lindworsky

As we will see, Lindworsky used Störring's experiments as a starting point for his own experiments (Lindworsky, 1916a, V), which intellectually connects the both of them within the domain of early experimental reasoning research. But are there other connections or is it plausible that they met in person? In Bonn, where Lindworsky studied until 1913 and Störring taught from 1914 onward, they missed each other by one year, but it is possible that they met at the *IX. Conference for Experimental Psychology*, which took place in Munich from April 21 to April 25 in 1925 (Lersch, 1925, 586). Both Störring and Lindworsky attended this conference and gave talks there (see Lindworsky, 1926b;

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[6] Some works were published in Spanish, Dutch, Italian, English, Polish, French, or Portuguese. Out of the five publications, the most frequent languages were Spanish (4 works) and English (4 works). It is noteworthy that one of the English translations of Lindworsky's *Experimental Psychology*, published in 1940 in Beijing (1940), presents a version of this text which was meant to be accessible to Chinese students, with Chinese annotations to the English text.

G. W. Störring, 1926c). Lindworsky gave a short talk on how the meaning of words is apprehended (Lersch, 1925, 594; Lindworsky, 1926b, 193 ff.). In his talk at this conference, Störring talked about his experiments on hypothetical and disjunctive reasoning (G. W. Störring, 1926c, 225 ff.).[7] This would have provided an opportunity for discussion and Lindworsky might well have attended this talk, even if his own research already took different directions at this time. Apart from Störring and Lindworsky, Karl Marbe and Karl Bühler also attended the conference (Bühler, 1926, III; Lersch, 1925, 591). Lindworsky and Störring also both participated in the creation of the journal *Archiv für die gesamte Psychologie* (see, e.g. Wirth, 1930). Although they did not appear as editors, the journal was made "in collaboration with" Störring and Lindworsky, among others (Wirth, 1930, I; own translation). Lastly, as we will see below that both of them were significantly influenced by the Würzburg School.

Störring's and Lindworsky's Pioneering Experiments on Deductive Reasoning

Störring's *Experimentelle Untersuchungen über einfache Schlußprozesse* (1908) and *Experimentelle und psychopathologische Untersuchungen über das Bewußtsein der Gültigkeit* (1909)

In his 1908 paper *Experimentelle Untersuchungen über einfache Schlußprozesse*, Störring focused on two issues in the psychology of reasoning, which he intended to investigate experimentally (1908, 1 f.). Those were, in his own words: "F. A. Lange's notion that all reasoning is done on the basis of spatial perception. [...] Similarly, the

[7] Even though this is a significant amount of time after Störring's and Lindworsky's initial experiments on deductive reasoning, we can see that Störring's talk was on reasoning, which could have prompted him to talk about this topic with Lindworsky. We should also take into consideration that Störring did publish a book on reasoning in 1926 (1926a) as well as two articles on reasoning in 1925 (1925) and 1926 (1926b). In addition, as we have already mentioned, he prompted one of his sons to do experiments on reasoning: W. Störring (1925). Lindworsky had published, as mentioned above, a re-evaluation of the results of *Das schlußfolgernde Denken* in 1922 (1922).

controversy around the significance of the synthesis of the relations of the premises for the realization of the conclusion made an impression on me" (G. W. Störring, 1908, 1; own translation). Because of this first issue, Störring's paper was not only the first experimental paper on deductive reasoning, but also "the first attempt to study the role of imagination and visual representation in human logical reasoning" (Knauff, 2013, 7).

The procedure of Störring's experiments was as follows: the participant sat in a room enclosed by a black cloth into which one end of a square lens tube (*Tubus*) had been placed obliquely, forming the angle at which one normally reads a book (G. W. Störring, 1908, 2). The other end of the lens tube was covered by a curtain and pointed toward the surface of a small desk (G. W. Störring, 1908, 2). When the curtain was lifted, the participant saw a piece of paper at circa 30 cm distance on which the premises were written (G. W. Störring, 1908, 2). We can assume that by taking these measures Störring wanted to minimize influences of outside factors on the experiment. Störring's teacher Wilhelm Wundt had been criticizing the lack of such measures in contemporary introspective experiments (Wundt, 1908, 447). Apparently, his student Störring was an exception to this rule. Störring mentions also experiments by G. Cordes, who took similar measures (G. W. Störring, 1908, 2). Approximately 1.5 seconds before the curtain was lifted, the instructor gave the signal "soon", and when the curtain was lifted, he gave the signal "now" (G. W. Störring, 1908, 2). "The participant was [then] instructed to reason with the consciousness of absolute certainty" (G. W. Störring, 1908, 3; own translation). At first, this instruction was repeated before every experiment[8] (G. W. Störring, 1908, 3). Sometimes, the participants additionally received other instructions (G. W. Störring, 1908, 3). "The time from the beginning of the exposure [of the participant to the premises] until the beginning of the[ir] uttering of the conclusion was measured with a quintuple-second

[8] Störring does not specify, whether he means that his instructions were repeated before every task or before every trial, but we can assume that he means that they were repeated before every trial, because this is what he says in G. W. Störring, 1909b, where his experimental conditions were the same (1909b, 1 f.).

clock" (G. W. Störring, 1908, 3; own translation). Störring then "asked his subjects to draw the conclusion [from the given premises], and to report on how they did it" (Gordon, 1917, 191).

Here we can clearly see that Störring used the method of introspection in his experiments. This method was accompanied by controversies about their validity. One of them is called the *Wundt-Bühler Controversy* today and can be seen as a controversy between Wundt and the Würzburg School which was also aimed in particular at Karl Bühler. Wilhelm Wundt, was against investigating individual or higher consciousness with the help of the introspective method (Danziger, 1994, 18; Thomae, 1977, 36 f.):

> "In his relatively well-known attack on the method of the Würzburgers, Wundt was of course expressing his opposition to the entire trend [of introspection.] He reiterated that only when "the objects of introspection are directly tied to external physical objects or processes" did one have ideal conditions for experimental psychological investigation" (Danziger, 1994, 43).

Another point of criticism that Wundt brought forth against introspection was that the reproduction of the participants was not a reproduction of their inner experience, but the attempt to reconstruct their experiences from memory and this could, according to him, only have happened if these experiences had been observed while they were happening (Wundt, 1908, 450 f.). The results could therefore be biased by or wrongly retrieved from memory. Störring, in contrast, asked his participants to not practice introspection during the experiment itself and told them to rather concentrate on the experiment (G. W. Störring, 1908, 3). He also sometimes gave other instructions, for example, he asked the participants to react quickly (G. W. Störring, 1908, 17). In what way Wundt's criticism did indeed extend to Störring's or even Lindworsky's work and their reception is not clear. However, we can see that his student Störring did try to avoid, as we have seen, some of the critical arguments that Wundt aimed at Bühler.

The participants in Störring's experiments were four students, two of which were

women and three of which were students of the humanities (G. W. Störring, 1908, 4). Störring experimented with simple and categorical syllogisms, but excluded categorical syllogisms with dependence relations (G. W. Störring, 1908, 2). He used logical arguments which consisted of letters (G. W. Störring, 1908, 2). An example of an argument form with spatial relations (including a conclusion) would be: "T is to the left of B, K is to the left of T; therefore K is to the left of B" (1908, 5; own translation). Within this type of argument, but also concerning others, he differentiated between *simple* and *complex* arguments (G. W. Störring, 1908, 5, 14). The given example is one of the simple arguments. As an example of a complex spatial argument Störring gives the following: "Participant K. Exposed was: S is to the left of D, K is to the right of D. Therefore. . . " (G. W. Störring, 1908, 15; own translation). Störring usually does not present detailed literal quotes of the introspective reports of his participants, but provides summary descriptions. Here is one of the more detailed examples:

> "Participant E. Exposed was: S is left of D, R is right of D. Therefore . . . [. . .] While reading the premises the participant noticed the inclination to connect both premises. While reading, spatial images were not noticeable. But when the participant started to express the conclusion, spatial images were present. When the participant started uttering the conclusion, the conclusion was not yet completed, but they had the consciousness: it is coming. Participant said S and had the *"consciousness of having completed all the requirements for the uttering of the conclusion until further concentration"* Thereby, [a feeling of] security was present that they should start with S" (G. W. Störring, 1908, 10; own translation).

Another type of argument Störring experimented with were arguments with temporal relations (G. W. Störring, 1908, 31). An example of premises featuring temporal relations from which the participants had to draw a conclusion is the following: "Procedure L [occurred] earlier than procedure S, Procedure Q [occurred] earlier than procedure L.

Therefore . . . " (1908, 32; own translation). A third and fourth type of argument he used were those containing the relations "bigger than" and "smaller than", and "arguments with identity relations" (G. W. Störring, 1908, 53, 65; own translation). Lastly, Störring also dealt with "arguments with subsumption relations" (G. W. Störring, 1908, 76; own translation). He provided the following premises for one of the arguments of this type: "All p belong to the genus a, all a belong to the genus d. Therefore. . . " (1908, 78; own translation).

In a discussion of Störring's work, Edward Bradford Titchener rightly observed that Störring's 1908 paper is not easy to follow:

> "The paper [*Experimentelle Untersuchungen über einfache Schlußprozesse*] has no summary; nor is there any explicit reference in the text (save that to space, 77 f.) to the problems mentioned in the introduction: the reason is, perhaps, that the present investigation, with visual material, is to be supplemented by another, in which the premises are to be given in auditory form" (Titchener, 1909, 271).

This auditory investigation is described in Störring's subsequent paper *Experimentelle und psychopathologische Untersuchungen über das Bewußtsein der Gültigkeit*, which will be mentioned again later. The fact that there is no explicit summary of Störring's paper in simple reasoning processes makes it difficult to discern the most important discoveries, as well as what Störring himself considers to be his most important discoveries. Jospeh Geyser, a contemporary of Störring, even denied that Störring's experiments were in fact experiments, because they were lacking in precision (1908, 378). Störring did, for example, not do the same experiments in the same order with each participant (Geyser, 1908, 378 f.). So even from a contemporary viewpoint, Störring's experiments were not as well executed as they could have been, which might be one of the reasons for confusion on the side of the interpreters. Geyser also notes that Störring tends to waver between his stance on the relationship between logic and psychology and in doing so loses his clarity (1908,

376 f.). He is not clear on what comes first in his scientific positioning: logic or psychology (Geyser, 1908, 376). Guy Politzer mentions further deficiencies of Störring's paper: "The paper [Störring 1908] has no explicit hypotheses, no experimental design, and no statistical treatment, and there were only four participants" (2004, 214). Additionally, no clear recruitment processes of the participants is mentioned and the small sample size is not justified. Such deficiencies would, in our view, not meet today's standards of psychological experimentation. However, Politzer also says that the observations made in this paper "certainly put it abreast with modern studies" (2004, 214).

All of that being said, one point on which most secondary literature agrees concerns the strategies that the participants employed. Geyser points out that Störring's participants did not report that they thought about logical rules while drawing their conclusions, but that they resorted to mental visualizations (1909a, 64). At several points in his study, Störring mentions that his participants saw "visual representations" of the premises (G. W. Störring, 1908, 11, 16, 28; own translation). As well as visualizations, they also used verbal methods to reason (Johnson-Laird, 2004, 185). Here, Störring differentiated between reasoning achieved by simple and reasoning achieved by complex relating (G. W. Störring, 1908, 53). According to him, the simple relating was a process, which was characterized by a synthesis of the relations in the premises and an identification of the different values whereby the conclusion could then be "read off" the premises (G. W. Störring, 1908, 53; own translation). The complex relating process is characterized by inserting information from one premise into the other premise (G. W. Störring, 1908, 98). This strategy of reasoning was first described by Aristotle, but did not gather a lot of attention (Stenning & van Lambalgen, 2011, 559). He called it the *ecthetic method* (Stenning & van Lambalgen, 2011, 559 f.). Philip Johnson-Laird and Sangeet Khemlani mention Störring's theory of "[v]erbal substitutions" as one of the "12 Main Theories of Syllogistic and Monadic Reasoning" (2012, 9). Their short description of the theory is the following: "Substitute one term in a premise for another term in another premise; for

example, given *Some A are B* and *All B are C*, infer *Some A are C*" (2012, 9).

In 1909, Störring published a similar experimental paper, which focused on a different aspect of the reasoning process. In *Experimentelle Untersuchungen über einfache Schlußprozesse* from 1908, Störring says that he found it useful to follow Oswald Külpe's suggestion to instruct the participants to observe different aspects of the same process in different experiments (1908, 3). This is what he expanded upon in the experiments preceding his paper from 1909, which is called *Experimentelle und psychopathologische Untersuchungen über das Bewußtsein der Gültigkeit* (G. W. Störring, 1909b, 1). Here, he focused on what he called the *consciousness of validity* (G. W. Störring, 1909b, 1), which is in today's terms a *meta-cognitive* reasoning process. Meta-cognitive processes refer to cognition about cognition (Flavell, 1976), a field of research which became important in the psychology of memory (Nelson & Narens, 1990) (e.g., when we know that we know something but can't presently remember it) and more recently in the psychology of reasoning (Thompson, Prowse Turner, & Pennycook, 2011; Ackerman & Thompson, 2014, 2017). Störring describes how such meta-cognitive processes manifest in the thoughts of participants:

> "In reasoning processes, the consciousness of validity occurs in this manner: I have to think like this, it is required to think like this, everyone has to think like this; I am sure, it is right, it is like this; it can't be any other way, this is the manner in which action has to be taken, etc. This consciousness is accompanied by words or occurs without words"(1909b, 3; own translation).

According to Karl Bühler, the *consciousness of validity* was something that was already well-known in logical research at the time (1910, 348). Störring says of the *consciousness of validity* that it is something that often occurs when one is instructed to draw a conclusion (1909b, 3). The consciousness of validity appears to be similar to the meta-cognitive concept of the *feeling of rightness* (of a validity judgment) which gained importance in recent years (Thompson et al., 2011; Ackerman & Thompson, 2014). We will come back to

this concept in our section on later developments in psychology.

Generally speaking, Störring's experimental conditions were the same as in *Experimentelle Untersuchungen über einfache Schlußprozesse* (1909b, 1). A separate description of the experimental setup, which he unfortunately does not give to the reader, might still have been necessary as the experiments differ from those he described in 1908 in one important point: some premises were given auditorily (G. W. Störring, 1909b, 4). Some premises were also given to the participants visually (G. W. Störring, 1909b, 18). Then again, for other premises, it is not clear how they were given to the participants as Störring writes that a certain participant was "exposed" to premises, but does not say in which way this was done (1909b, 5; own translation).

The participants then focused on a certain aspect of the reasoning process, which was of interest to them (G. W. Störring, 1909b, 1 f.). According to Störring, the interest of the participants could be caused by directions from the instructor given only at the beginning of an experimental trial, such as saying that a certain aspect, for example the *consciousness of validity*, was one of the aspects they wanted to investigate, but that the participant did not have to put their main focus solely on this aspect (1909b, 2).

During those experiments, Störring investigated premises with subsumption (e.g., *All E belong to the class A*) and inherence relations (e.g., *All E have the property P*),[9] with spatial and temporal relations, and with the comparative relations *bigger and smaller than* (G. W. Störring, 1909b, 2). He only used premises of hypothetical and disjunctive inferences (G. W. Störring, 1909b, 2). The premises themselves were similar to the ones he used in his previous experimental investigation. Störring worked with five participants, three of which had already participated in his previous experiments on reasoning (G. W. Störring, 1909b, 2). One of them was the physicist and philosopher Moritz Schlick,

[9] In his book on logic, Störring gives another example of inferences with a subsumption relation in one premise and an inherence relation in the other: "All A have the property B, All C (of this K) belong to class A, Therefore all C (of this K) have the property B" (1916, 223).

who had not participated in the previous experiments (G. W. Störring, 1909b, 2). Schlick was one of the founding members of the Vienna Circle, whose philosophy of logical positivism shaped analytic philosophy (Stadler, 2015).

The experiments described in *Experimentelle und psychopathologische Untersuchungen über das Bewußtsein der Gültigkeit* could be seen as an investigation into the different psychological processes that occur during a reasoning process. Störring placed importance on what participants think and feel during deductive reasoning. He was interested in investigating commonalities in the thought processes and emotions as indicators of internal psychological processes. An example of that is the distinction between what Störring calls "Bewußtsein der Gültigkeit" (the *consciousness of validity*) and "Zustand der Sicherheit" (the *state of certainty*) (G. W. Störring, 1909b, 3). It should be noted that in his talk *Experimentelle und psychopathologische Untersuchungen über das Bewußtsein der Gültigkeit*, Störring defines "Feststellung der Gültigkeit" (*determination of validity*) in the same way as he defines the *consciousness of validity*: namely, there has to be the thought in the participant, with or without words, that something is right and that they are certain of it (G. W. Störring, 1909a, 695 f.; G. W. Störring, 1909b, 3). The *consciousness of validity* occurs, on the condition that one has been asked to draw a conclusion from given premises mostly at the end of the reasoning process (G. W. Störring, 1909b, 3). According to Störring, it can occur "either after a question of validity or also without the thought of such a question being measurable" (G. W. Störring, 1909b, 3; own translation). Here he does not specify whether the question of validity refers to a question posed by the instructor or by the participant himself. Störring does dedicate a few pages of his paper to how the *consciousness of validity* is different in people with mental disorders, but does not mention having done any experiments to back up his claims (1909b, 9 ff.).[10]

It can be assumed, even though it should be stressed that Störring does not state this

[10] His talk at the *III. International Congress for Philosophy* in Heidelberg suggests that there were indeed no experiments done on the process of reasoning with mental disorders (1909a, 692).

explicitly, that the instructor asked the participants, after they had drawn a conclusion, whether they thought that their conclusion was right ("Frage nach der Richtigkeit"; see G. W. Störring, 1909b, 5 ff.). This is where the *state of certainty* comes into play: Störring describes the *state of certainty* as something that causes one to answer "the question of rightness", presumably the rightness of a certain conclusion in relation to the given premises, affirmatively (1909b, 9). An important component of it is a "feeling of necessity" (G. W. Störring, 1909b, 18; own translation). But this *feeling of necessity* does not have to be present at every step of the reasoning process (G. W. Störring, 1909b, 19):

> "The feeling of necessity is experienced where a step [of the reasoning process] is under the influence of the thought of opposition or identity of the relations expressed in the premises or where an insertion takes place, often mixed with an *active feeling*. I receive such information from participant K., participant E. and participant Schl." (G. W. Störring, 1909b, 20 f.; own translation).

Störring observed that the *state of certainty* in the participants is strongest when they not only have to draw a conclusion, but also deliver a justification for it (1909b, 12). He emphasizes that in those cases the *state of certainty* even reaches a level that cannot be increased (1909b, 15 f.). This absolute form of certainty is, for him, a criterion for the truth of statements (1909b, 16; 1909a, 696).

Another interesting observation that Störring makes is that with premises with spatial relations, the reasoning process sometimes produced bodily responses in the participants (1909b, 24 f.). Some participants, for example, had the tendency to move their right arm when dealing with the spatial relation "to the right of" (G. W. Störring, 1909b, 25; own translation).

Lindworsky's *Das schlußfolgernde Denken (1916)*

Through the experiments he presented in 1916, Lindworsky wanted to answer the question of how people reason deductively (Lindworsky, 1916a, vi). He took note of

Störring's experiments, tried to expand upon his results, and improve them (Lindworsky, 1916a, v f.). For example, Lindworsky used premises with content for his task material, because he doubted that Störring's results from abstract letters could be universally applicable (Lindworsky, 1916a, v). For example, Lindworsky used task material like following: "Asps are non-poisonous. – Some colubrids are asps." (Lindworsky, 1916a, XV; own translation). For this task, one of Lindworsky's participants gave the following solution:

> "... Namely after "asps" I immediately heard the word "non-poisonous", and indeed this was not *a mere succession*, but it was already the conclusion, phrased incompletely, (it) did still represent the issue; meaning: are therefore non-poisonous" (Lindworsky, 1916a, 36; own translation).

Another participant gave this introspective report for the same task: "... Apprehended the second sentence. [It r]emains undecided what colubrids are. [...] *Internally, acoustically it was very clear*: "are non-poisonous", and *that presented itself to me as the resolution of the inference. Had to then search what (who) was non-poisonous. Slowly, the word returned; then I was too lazy to repeat the predicate*" (Lindworsky, 1916a, 36; own translation).

He also pointed out that Störring did not deal with simple reasoning processes in his experiments on reasoning (1916a, v). This was something that Lindworsky attempted to rectify in his experiments. *Das schlußfolgernde Denken* is thus split into two parts. The first and main part, which contains his whole PhD thesis, *Die Gestaltungsweisen des syllogistischen Denkens* (1916b), is about syllogistic reasoning, the second part about natural reasoning. What Lindworsky calls *natural reasoning* is reasoning, which does not function according to the laws of logic and occurs in our daily lives (Ihmels, 1917, 128). Hence, natural reasoning goes beyond truth-functional deductive reasoning.

In contrast to Störring, Lindworsky's experimental report is better structured. At the beginning, he gives an overview on his task material. Like Störring, he explains in his introduction how his experiments were conducted. At the beginning of each of the two

sections of his main part there are also methodological sections, tailored specifically to the types of reasoning processes he deals with in each of the two main parts. Lindworsky had 12 participants in his experiments (Lindworsky, 1916a, vi). One of them was the psychologist Karl Bühler (Lindworsky, 1916a, vi).

For his experiments on syllogisms, Lindworsky used Aristotelian syllogisms, in particular the first two syllogistic figures (Lindworsky, 1916a, 15). He focused only on them, because he found the other two to be too difficult for his participants (Lindworsky, 1916a, 15). In total, he used 130 different tasks (Lindworsky, 1916a, 15 f.). An example of the premises Lindworsky's participants were to consider would be: "Poplars are fast-growing trees. – Aspens are poplars" (1916a, xv; own translation). At first, the premises were mostly given visually on a piece of paper, and, after the participants had gotten used to the types of premises, also auditorily (Lindworsky, 1916a, 18). Comparing Störring's experimental setup to his own, Lindworsky states:

> "Störring's measure to let the task be read through a tube seemed, especially with syllogisms which were not constructed with letters but with words, unsuitable. The few stimuli which the tube would be able to keep away would not compare to the internal distractions from which the participant cannot be protected. The premises were written very clearly on octave notes, at first by hand, later typewritten. This showed a great independence of the participant from the external form of the stimulus" (Lindworsky, 1916a, 18; own translation).

We can therefore see that Lindworsky did consider the influence of outside stimuli on his experiments. Just like Störring, Lindworsky also used the method of introspection, which means he gave the instructions to draw a conclusion from the given premises and asked the participants to report on their experiences during the reasoning process (Lindworsky, 1916a, 23).

Lindworsky's experiments were divided into analytic and synthetic test series after E.

Westphal (Lindworsky, 1916a, 4). An analytic test series is done with introspection (Lindworsky, 1916a, 4). The synthetic test series can be done by either varying the instructions or the experimental setup and mainly serves the purpose of making sure that the instructor has understood what a participant said in the analytic test series (Lindworsky, 1916a, 4). This type of test series was therefore intended to be a recreation of the initial experience in the analytic test series (Ühlein, 1986, 46). The instructor also asked what Lindworsky called "additional questions", which were about the report of a participant (e.g. "Which character had the occurrence of the solution?" (Lindworsky, 1916a, 23; own translation) or "Did you use any tools? Spatial or logical schemes?" (Lindworsky, 1916a, 23; own translation)) and "exploratory questions", which showed the participant a new aspect for introspection (1916a, 6; own translation). In the first analytic test series the instructor only asked additional questions and in the second analytic test series he also asked exploratory questions (Lindworsky, 1916a, 6). According to Lindworsky, the synthetic test series should have also had this two-part structure, but it was only during his experiments that he developed this method and therefore he did not implement it in the way he would have wanted to (1916a, 7).

By making *natural reasoning* the second topic of his experiments, Lindworsky wanted to investigate the natural advancement of knowledge (Lindworsky, 1916a, 225). His central research question was: "Under which conditions do we accomplish an advancement of knowledge in our [daily] lives whose source is not solely our perception?" (1916a, 226; own translation). Here, he used different task materials: "short riddles of different kinds, invention-, detective-, and joke tasks, mathematical [tasks], and especially "combination tasks"" (Lindworsky, 1916a, 226; own translation). The tasks ranged from questions like "What can you still say with certainty when you hear: X has become an uncle?" (1916a, 258; own translation) to unfinished sentences like: "Newspapers are the . . . of history" (1916a, 255; own translation).

The experimental situation as a whole was meant to be as natural as possible

(Lindworsky, 1916a, 230). Most tasks were given to the participants visually on a piece of paper, which was covered by another piece of paper, which the participant had to remove (Lindworsky, 1916a, 230 f.). The task material was not given in a specific order and mixed with syllogisms (Lindworsky, 1916a, 231). As each task was different the instructions also varied (Lindworsky, 1916a, 231). The examiner said, for example: "You are going to receive a sentence with a gap in it. Your task is to fill the gap analogously" (1916a, 231; own translation).

In what Lindworsky calls *Wirklichkeitsversuche*, which roughly translates to *reality experiments*, the participants received the instruction that they should try to see things from a described perspective and to state which conclusions they were able to draw from that (Ihmels, 1917, 128). One of the scenarios Lindworsky gave to his participants was the following: "On the morning of a very cold winter day you step outside and realize: the cold has subsided. What do you suspect?" (1916a, 249; own translation).

In Lindworsky (1916a), Otto Selz is mentioned a few times (e.g., 239 f., 253, 307, 323 f.). Specifically, Lindworsky adopts Selz's (1913) terminology, such as the phenomenological *Leistungsanalyse* (achivement analysis) (Lindworsky, 1916a, 97) and uses the concepts of *Wissensaktualisierung* (knowledge actualization) (Lindworsky, 1916a, 239 f., 323 f.) and the *Gesetz der Berichtigung* (law of correction) (Lindworsky, 1916a, 323 f.).

Lindworsky's most important result was that reasoning is often an act of apprehending relations (Lindworsky, 1916a, 445 ff.). The conviction that this act of apprehending relations was the main process of thinking was one he would hold until 1924 when he published his paper *Revision einer Relationstheorie* (Ühlein, 1986, 72).[11] What exactly Lindworsky meant by a *relation* is best explained in his own words:

> "The statement—*A* is greater than *B*—denotes a material relation. We attach a very definite content to the expressions "equal," "greater," "above," "right,"

[11] This paper, according to Ühlein, also concludes the first phase in Lindworsky's psychology of thinking, which is defined by the process of apprehension of relations (1986, 80).

> and so forth. We mean by them something else than merely the sum of both things; we mean that between them, there is a prevailing *relation*" (1931, 151).

According to Lindworsky, the apprehension of relations could also be of use in intelligence testing (1916a, 450 ff.), which is something he went into detail about in a paper he published in 1920 (Ühlein, 1986, 51). In 1922, Lindworsky published another re-evaluation of the results of *Das schlußfolgernde Denken*, which was done with frequency tables (Lindworsky, 1922; Ühlein, 1986, 52, 71).

Another important result of Lindworsky's first experiments on deductive reasoning was that in order to solve the syllogistic tasks, the participants used either *reproductive* or *conceptual* solutions (Ühlein, 1986, 60 f.). When the solution was a reproductive one, the participants often described that the solution had imposed itself on them (Lindworsky, 1916a, 27 ff.). The conceptual solutions can again be divided into those solutions where the *middle term*[12] was used to solve the syllogism and those where it was not (Ühlein, 1986, 61). For the latter, the participants tended to work with imagination of concrete things instead of words (Lindworsky, 1916a, 88 ff.).

Lindworsky also noted a difference in how the participants dealt with the premises: some dealt with them *formally* and some *factually* (1916a, 19 ff.). "The formal [mode of behavior] dealt with the premises as if they consisted of letters instead of words[. . .] The factual [mode of behavior] dealt with the content of the given sentences" (Lindworsky, 1916a, 19; own translation). Which of those modes of behavior a participant adopts depends on them as an individual and on how the task material is presented to them (Lindworsky, 1916a, 20 ff.). Lindworsky attributed the fact that Störring's results differed from his to the different material that was used in both experimental studies (1916a, 207).

Another important result of Lindworsky's experiments was the observation that the participants did not reason by syllogisms in order to solve the natural reasoning tasks (Lindworsky, 1916a, 445). Furthermore, with regard to his question about the

[12] In Aristotelian syllogisms, the middle term only occurs in the premises.

advancement of knowledge, Lindworsky's answer is: "In the cognitive processes we have examined, the apprehension of relations is the only provable principle of a progression of knowledge" (Lindworsky, 1916a, 294; own translation).

A small part of *Das schlußfolgernde Denken* is made up of additional syllogistic experiments with students aged ten to eighteen (Lindworsky, 1916a, 219). There, Lindworsky found that even younger students, who had not yet been taught syllogistic reasoning, were able to reason syllogistically (Lindworsky, 1916a, 221 f.). This can be seen as an early contribution to the developmental psychology of deductive reasoning. Specifically, Lindworsky presents a first attempt to investigate how the reasoning competence develops from children to adolescents, roughly a decade before Piaget's famous work on the developmental psychology of reasoning (see, e.g. Piaget, 1928).

Later Developments in Psychology

To illustrate the relevance of Störring's works in the psychology of reasoning, we want to show that he can be seen as a precursor to later developments in this field. Firstly, there is an argument that with the *consciousness of validity* Störring described an early form of what would later come to be called the *feeling of rightness*. The feeling of rightness is defined as the "degree to which the first solution that comes to mind feels right" during the reasoning process (Ackerman & Thompson, 2017, 608). If it is strong, further reconsideration of the solution is not required by the reasoner. However, if it is weak, it is "accompanied by longer periods of reconsideration and a higher probability of changing answers" (Ackerman & Thompson, 2017, 612). Interestingly, the feeling of rightness and the participants' final confidence in the correctness of their solutions are not necessarily highly correlated with *accuracy*, i.e., with the normatively correct solutions. Hence, also the consciousness of validity in Störring's sense cannot be generally expected to coincide with correct judgments of logical validity. Störring's concept of the consciousness of validity is hence an early precursor of the feeling of rightness.

According to Uwe Oestermeier, Störring already developed a similar hypothesis of how people reason to the one Johnson-Laird would develop several decades later, even if Störring was missing one step in Johnson-Laird's reasoning process (1998, 189 ff.). Johnson-Laird argues that people draw conclusions with the help of so-called *mental models*, which function as mental representations of logical premises and can aid in drawing a conclusion (Khemlani & Johnson-Laird, 2012, 17 ff.). As we have already touched on, Störring originally tried to experimentally verify the role of spatial representations in the reasoning process, which others had postulated before him (G. W. Störring, 1908, 1). During the process of experimentation, he also came to look at other types of mental representation, not only spatial ones (Oestermeier, 1998, 189 f.). An example of such a mental representation or visualization during a reasoning process, but also of the thought processes behind a reasoning process is given by Störring:

> "Participant F. Exposed was: Procedure *V* [occurred] earlier than procedure *J*, procedure *W* [occurred] earlier than procedure *J*. Therefore... After reading and comprehending the first premise, the participant asks himself: how do I imagine this? Answer: First *V*, then *J*, at the same time *V* was localized on the left, *J* on the right. This clarification was then repudiated. [...] Then the participant imagined the relation solely temporal with the memory of bell chimes: [...]
>
> Then the spatial representation was repeated. After that the thought occurred that both representations are possible here. In the end the participant decided in favor of the temporal representation without visual imaginations"
> (G. W. Störring, 1908, 33; own translation).

According to Guy Politzer (2004, 215), the visualization strategy was rediscovered by Marilyn Ford (1995). Politzer also mentions another observation made by Störring in his 1908 paper, which later came to be known as the "figural effect" (Politzer, 2004, 213 ff.). The term *figural effect* refers to the observation that participants' response latencies may depend on the order of the premises (Johnson-Laird & Bara, 1984). For example,

inferences from "all S are P; all P are M" (minor/major premise order) are usually drawn faster compared to inferences from the same premises, when they are presented in reversed order "all M are P; all S are M" (major/minor premise order).

As already mentioned, Störring also made observations regarding bodily responses in his participants. On the one hand, some participants had the tendency to move their right arm to the right when dealing with the spatial relation *to the right of* (G. W. Störring, 1909b, 25), but there were also participants who had sensations in their arms when dealing with temporal relations:

> "Participant K. Exposed was: Procedure N [occurred] later than procedure Z, procedure U [occurred] earlier than procedure Z. Therefore... [...] After reading the first premise, N is immediately localized behind Z on the surface of the exposed piece of paper. After reading the second premise the U is matched with movement sensations of the left arm to the left. Then occur movement sensations of the right arm to the right and the *consciousness of two opposite directions*, starting from Z, whereby Z occurs less clear in the conscious mind, emerges. Then the reasoning takes place: U is left of the center point Z – and N lies in the opposite direction, to the left, therefore U is earlier than N" (G. W. Störring, 1908, 42; own translation).

These observations of the involvement of such bodily movements during the reasoning process points to a research direction which has come to be known as *enactive* or *embodied cognition* (Varela, Thompson, & Rosch, 2017; Newen, De Bruin, & Gallagher, 2018). Embodied cognition is "the idea that the body or the body's interactions with the environment constitute or contribute to cognition" (Shapiro & Spaulding, 2021). You could go even further than that: in what is called *extended cognition* "the environmental and social resources [...] are in fact *constituents* of a larger cognitive system" (Shapiro & Spaulding, 2021).

Störring's and Lindworsky's Connections to the Würzburg School

After recalling some basic information about the Würzburg School, we investigate connections between this school of thought and Störring and Lindworsky in the following sections to show that they can indeed be counted as psychologists in the Würzburg tradition as well as how they were influenced by the Würzburg School.

The Würzburg School

It is commonly suggested that the Würzburg School was founded in the perimeter of the psychologist and philosopher Oswald Külpe, a student of Wilhelm Wundt (Gundlach, 1999, 114), who is also seen as the founder of the modern psychology of thought processes (Kopp & Mandl, 2020, 308).[13] Külpe was professor for philosophy, which was at the time strongly affiliated with psychology, in Würzburg from 1894 until 1909 and contributed to building the psychological institute there from 1896 onward (Schneider & Stock, 2020). The Würzburg School of thought is well-known for the experiments on higher mental processes, which were conducted by its members, who were mostly Külpe's students (Galliker, Klein, & Rykart, 2007, 251 f.; Mülberger, 1997, 226), apart from the independent thinker Karl Marbe who was never a student of Külpe (Mülberger, 1997, 226). Other prominent members of the Würzburg School include Otto Selz, Narziß Ach, and Karl Bühler (Galliker et al., 2007, 254) and also August Mayer, Johannes Orth, Henry Jackson Watt, and August Messer (Gundlach, 1999, 112). The most important research area of the Würzburg School was the psychology of thought processes: although, deductive reasoning is such a process, abstract logical reasoning was not yet investigated systematically. The key research method

[13] We note that there are researchers, who contest the commonly held belief that Külpe was the sole founder of the Würzburg School (see Gundlach, 1999, 113 ff.; Mülberger, 1997, 226). Apparently, it was Karl Marbe who contributed substantially to the construction of the school and became the school's second director in 1904 (Mülberger, 1997, 225 f.), until he left Würzburg for Frankfurt one year later, before coming back to Würzburg as a replacement for Külpe, who left in 1909 (Mülberger, 1997, 225; Schneider & Stock, 2020).

of the Würzburg School was introspection (see Pritzel, 2016, 328; Mülberger, 1997, 227):

> "The Würzburg School's method for studying thought processes was a combination of traditional armchair psychology with modern laboratory technique.[footnote omitted] The process of introspection was distributed over two psychologists: the experimental subject would observe and report his mental experiences, whereas the experimental organizer (*Versuchsleiter*) would evoke the experience, record the subject's report, and possibly ask for further clarifications" (Kusch, 1995a, 263).

As we will show in the next sections, Störring and Lindworsky expanded the domain of thinking research to systematic experimental investigations of simple deductive argument forms and Aristotelian syllogisms.

Störring's Connections to the Würzburg School

There is a lot of evidence that points to the fact that Störring and Lindworsky were part of the Würzburg School. The philosopher Joseph Geyser, for example, mentions Störring as a member of the Würzburg School (1909b, 20). Albeit, Geyser talks about experiments done at the psychological department in Würzburg and Störring obtained his doctorate in medicine, but not psychology, in Würzburg (Stöwer, 2003, 9). However, at this time, Külpe was already a professor in Würzburg, which could have prompted meetings between the two.

Interestingly, in the introduction of his *Experimentelle Untersuchungen über einfache Schlußprozesse*, Störring mentions having been inspired to conduct his experiments on deductive reasoning by members of the Würzburg School, specifically Watt and Messer (1908, 2). According to Annette Mülberger (1997, 233), Watt and Messer, in turn, were assigned this research in the psychology of thought processes by Külpe, after he had participated in the experiments for Karl Marbe's 1901 book *Experimentell-psychologische Untersuchungen über das Urteil*. Marbe wanted to gain knowledge about what judgments

were and how they could be distinguished from other processes of consciousness (Marbe, 1901, 15). For this, he conducted experiments where he tasked his participants to make different judgments (Marbe, 1945, 12), and then give introspective accounts of this process (Marbe, 1901, 16 ff.). The kinds of judgments Marbe focused on were experiences which could be said to be wrong or right (Marbe, 1901, 9 f.; 44), and those judgments could be sentences, words, movements or states of consciousness (Marbe, 1945, 11). He did, in contrast to Störring and Lindworsky, not include judgments of the validity of deductive arguments in his experiments. Marbe, for example, tasked his participants with estimating the heaviest object out of objects, which differed in weight, or the lightest color shade out of gray papers, which differed in shade (see Marbe, 1901, 17 ff.). He also gave mathematical tasks or simple questions concerning knowledge about the world to his participants (see Marbe, 1901, 27 ff.). Marbe can essentially be credited with his insight that it is possible to investigate judgments experimental-psychologically (Marbe, 1901, 93). Following this, Marbe demanded that in the future, all claims about psychological judgments should be based on experiments (Marbe, 1901, 94). Marbe can thus be seen as an important precursor of Störring, even if he is not mentioned in Störring's seminal paper. He helped to establish that psychological judgments were even a valid subject for psychological experiments. Compared to what Störring and Lindworsky did after him, Marbe's research was more basic and was concerned with what a judgment is in a relatively broad sense and how it differs from other processes. Störring and Lindworsky were much more concrete in their research interests: they looked at how people reason logically and what strategies they used. It is clear that they stand in the same tradition.

In the terms and concepts Störring uses to analyze his experiments on deductive reasoning, he also bears resemblance to the Würzburg School. As we have seen, Störring uses meta-cognitive concepts like "consciousness of validity" or "state of certainty", which are similar to what Karl Marbe called "Bewusstseinslagen" ("states of consciousness") (Von Aster, 1908, 60). Marbe specifically talked about "states of consciousness of validity"

and "states of consciousness of incorrectness" (Von Aster, 1908, 60). In the reading of the Würzburg School, "Bewusstseinslagen" were contents of thought (Kusch, 1995a, 148). That is in accordance with how the "consciousness of validity" showed up for Störring's participants: As we have already discussed, they had the thought that something was right or that something had to be done in a certain way. This is how the "Bewusstseinslagen" were generally defined, according to Martin Kusch:

> "Initially [Bewusstseinslagen] were defined only negatively, as those "facts of consciousness" that cannot be characterized in terms of sensations, presentations, and feelings. Subsequently, Marbe, Messer, and Watt distinguished between *Bewusstseinslagen* of various kinds, such as those of doubt, of understanding, and of temporal relations" (Kusch, 1995b, 422).

This is especially interesting considering that Störring was influenced by Messer and Watt.

Störring also had close proximity to Oswald Külpe: when Störring became professor for philosophy and psychology in Bonn, his predecessor in this position was Külpe (Stöwer, 2003, 12). Both Külpe and Störring felt that they needed to carry on the work of their common predecessor at this professorial chair, Benno Erdmann (Baumann & Wich-Reif, 2018, 564). Erdmann had implemented the teaching of a very broad spectrum of philosophy, which also encompassed experimental approaches (Baumann & Wich-Reif, 2018, 564).

Thyssen and Thomae mention that Störring was influenced by Külpe with regard to the use of introspection in his experiments and that he even took up suggestions of Külpe and his students: regarding the experimental analysis of states of consciousness, Störring should focus on intrapsychic processes (1968, 85 f.). According to the psychologist Theo Herrmann, Störring was also methodically influenced by the Würzburg School:

> "His experimental methods [in G. W. Störring, 1908] in principle followed the Würzburg strategy: highly sophisticated participants solved, among other

> things, syllogisms, and stated what they had experienced during this process" (2006, 21; own translation).

This, of course, also refers to the process of introspection, which Störring used in his experiments on deductive reasoning. Titchener introduces another point of similarity:

> "Störring's work, again, touches that of the Würzburg School at various points,—as regards the influence of the *Aufgabe*, or as Störring calls it, the *Anweisung*, the instruction; as regards the mechanics of introspection, and so on" (1909, 153).

Galliker et al. describe this influence of the *Aufgabe* in Külpe's work:

> "According to Külpe (1920), the instruction [Aufgabe] itself has a selective function regarding its execution. In this way, stimuli, which are relevant for the task are considered, while irrelevant stimuli are not" (2007, 255; own translation).

Indeed, in his experiments on deductive reasoning, Störring did give instructions, which were geared towards showing the participants which aspect of the experimental experience was important (G. W. Störring, 1908, 3). The principle of trying to avoid unnecessary stimuli can also be seen in the experimental setup of Störring's 1908 paper, where he, for example, let the participants look through a lens tube. The lens tube, of course, served to cover irrelevant stimuli. As already mentioned, this was also a point of consideration for Lindworsky in his experiments.

Furthermore, there are conference reports, which show that Störring had the opportunity to meet members of the Würzburg School: in 1908, Störring gave a talk at the *III. Internationalen Kongress für Philosophie* (*3rd International Congress for Philosophy*), in Heidelberg. His talk was about his experiments on reasoning (G. W. Störring, 1909a). Bühler and Külpe also attended this congress (Elsenhans, 1909, 546, 659). At the *7th Congress for Experimental Psychology* in Marburg in 1921, Störring also gave a talk

(Bühler, 1922, IV). The conference report for this conference was written by Karl Bühler. At the time of the conference, Lindworsky was a member of the society which organized the conference (Bühler, 1922, 190). It is, however, not clear whether Lindworsky also attended this conference. As already mentioned above, there was a congress for experimental psychology in Munich in 1925, which Bühler, Störring, Lindworsky, and Marbe attended (Lersch, 1925, 586, 591, 594; Bühler, 1926, III f.).

All of this taken together can be seen as strong evidence that Störring was a psychologist of the Würzburg School. Most importantly, we have presented evidence that key parts of his experiments on deductive reasoning were significantly influenced by the Würzburg School. There was also ample opportunity for personal meetings with members of the Würzburg School before and after the publication of his first experiments on deductive reasoning.

Lindworsky's Connections to the Würzburg School

As far as Lindworsky is concerned, there is secondary literature which calls him a member of the Würzburg School (see Stubbe, 2019, 44; Siwek, 1959, 176; Wendt, 2020, 6; Kusch, 1999, 18 f.). According to the psychologist Wolfgang Mack, Lindworsky is even one of the researchers who are most frequently mentioned as members of the Würzburg School (1994, 141). The psychologist Inga Rapp states that even though Lindworsky was influenced by the Würzburg School, he forms his own tradition based on the results of his experiments (2018, 20). Herbert Ühlein, whose PhD was the first full-length book on Johannes Lindworsky, thinks that at the beginning of his career, Lindworsky was a psychologist of the Würzburg School (1986, 58 ff.). This is exactly what matters to us here, because our focus is on Lindworsky's early career, when he conducted experiments on deductive reasoning. For this period, we can safely say that he was influenced by the Würzburg School in a number of ways and can therefore be called a Würzburg psychologist.

As already mentioned above, Oswald Külpe taught psychology to Lindworsky during

his time in Bonn and later after he had returned to Munich. It was Külpe who convinced him to study deductive reasoning. Apparently even after Külpe left Würzburg, some of his colleagues or assistants worked on topics, which were closely related to the works of the Würzburg School (1998, 52). An example is Lindworsky's dissertation, which was supervised by Külpe (Lindworsky, 1916a, VI f.). Külpe's assistant at the time when Lindworsky started his dissertation in Bonn was Karl Bühler, whose work Lindworsky had been interested in since 1907 (Ühlein, 1986, 24). According to the philosopher Martin Kusch, "Bühler's thoughts were taken up, and developed further, by students and collaborators of Külpe and Bühler. [. . . Among others by] J. Lindworsky (1916) in his analysis of inferences" (1999, 29). Indeed, Lindworsky's work was significantly influenced by Bühler:

> "Lindworsky saw himself only as one who completes BÜHLER'S life's work, because he [Bühler] had already taken the defining step [. . .] through BÜHLER, the significance of human creativity (this is especially finalized through the apprehension of relations) was moved to the center of attention" (Lebzeltern, 1969, 18 f.; own translation).

According to Charlotte Bühler, whom Gustav Lebzeltern quotes in his article on her husband Karl Bühler, the psychology of thought relations was a topic of research which Karl Bühler abandoned after having done some research in this field (Lebzeltern, 1969, 16 ff.). As already mentioned, the apprehension of relations is central to Lindworsky's theory of deductive reasoning. In the chapter on relations in *Das schlußfolgernde Denken*, Lindworsky states humbly that regarding those relations, which can be seen through language, his own experiments present no new findings compared to what Bühler already said about the topic (Lindworsky, 1916a, 412 f.).

Bühler, who is known for having been a developmental psychologist (Pritzel, 2016, 311), might also have been an influence on the aforementioned psycho-developmental aspect of Lindworsky's study on deductive reasoning. But this can only remain a speculation, as

Lindworsky does not refer to Bühler in the psycho-developmental part of *Das schlußfolgernde Denken*. It could, however, be a topic worth investigating in the future.

Karl Bühler also participated in Lindworsky's experiments and proofread his book *Das schlußfolgernde Denken* (Lindworsky, 1916a, VI f.). Lindworsky visited courses held by Bühler (Ühlein, 1986, 25). Especially during his second time in Munich, Lindworsky was in close contact with Bühler and was even invited to his wedding (Ühlein, 1986, 28). According to Lebzeltern, Bühler held Lindworsky's scientific achievements in higher esteem than he did those of Otto Selz (Lebzeltern, 1969, 18), whose lectures Lindworsky also visited (Wendt, 2019, 109).

Methodically, Lindworsky was also influenced by the Würzburg School: as mentioned above, he used the method of introspection for his experiments (Lindworsky, 1916a, 23). More specifically, Lindworsky was also influenced by Bühler's method for investigating imageless thought, which was introspection, combined with detailed questions about the participants' thought processes on the part of the instructor (Lindworsky, 1925, 159 f.).

To conclude, it can be said that Külpe and Bühler had a great impact on Lindworsky's *Das schlußfolgernde Denken*. Even though Lindworsky studied with them after Külpe had already left Würzburg, the work Lindworsky produced during this time still stands in the tradition of the Würzburg School. Like Störring, Lindworsky expanded the research domain of the Würzburg School to deductive reasoning.

Concluding Remarks and Future Research Directions

In this paper we contributed to filling a research gap in the history of psychology also relevant to philosophy, which has not been extensively explored. We see two reasons for this gap: firstly, there are no English translations of the above studied works by Störring and Lindworsky. Secondly, the author's methodological standards are not really comparable to nowadays methodological standards of experimental psychology (ranging from sample size, experimental design, controlled experimental conditions, use of inferential

statistics, etc., to APA standards of paper writing).

We have pointed out that Störring and Lindworsky were, at the beginning of the 20th century, the first researchers to conduct experiments on deductive reasoning. In his experiments, Störring discovered important strategies that participants used when they tried to solve syllogisms, as well as psychological processes, which occur during reasoning. Those psychological processes lead him to describe a psychological criterion for truth and to give a psychological characterization of a logical judgment. Lindworsky conducted experiments on syllogistic and natural reasoning. Based on his results he stressed that the act of apprehending relations plays an important role in reasoning. Regarding Störring's and Lindworsky's connections to the scientific community of their time, there is strong evidence in favor of the thesis that Störring and Lindworsky, and in particular their experiments on reasoning, stand in the tradition of the Würzburg School.

For future research, we suggest to evaluate Störring's and Lindworsky's positions within the scientific community, specifically regarding the Vienna Circle and the psychologism debate. Moreover, it could be fruitful to deepen investigations of potential impacts of the work of Otto Selz on Lindworsky.

The 20th century psychology of deductive reasoning was dominated by logic as the primary rationality framework. Hence logic shaped task materials, research questions, psychological theory building, and the way how the rationality of human inference was evaluated. Störring and Lindworsky are in this tradition of seeing logic as the gold standard in this domain. Since the beginning of the 21st century, a paradigm shift had occurred from logic to probability theory (see, e.g., Elqayam, Bonnefon, & Over, 2016; Pfeifer & Douven, 2014; Oaksford & Chater, 2020). As far as we can see neither Störring nor Lindworsky considered probability theory or probability logic as a rationality framework for human reasoning.[14] Therefore, although they cannot be seen as pioneers of

[14] Lindworsky (1916a, 316–319) mentions probability briefly as a qualification of some inferences but he did not consider reasoning about probabilities.

the probabilistic paradigm psychology of reasoning, both deserve the honor of being the pioneers of the psychology of deductive reasoning within the logic paradigm.

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