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The relationship between cyber/bullying, learning disorders and psychiatric comorbidity

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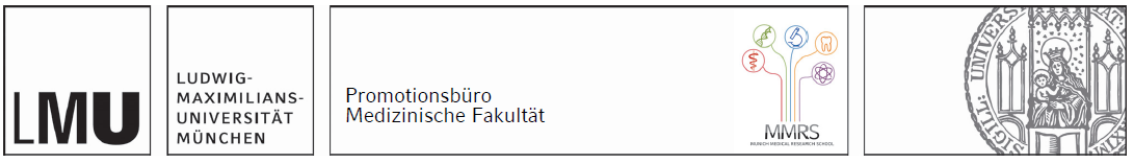

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Table of content

List of abbreviations

ADHD	Attention-deficit/hyperactivity disorder
LD	Learning disorder(s)
CD	conduct disorder
BPD	Borderline personality disorder

List of publications

Publications included in the cumulative dissertation:

Weinreich, L., Haberstroh, S., Schulte-Körne, G., & Moll, K. (2023). The relationship between bullying, learning disorders and psychiatric comorbidity. *BMC psychiatry*, *23*(1), 1-13. https://doi.org/10.1186/s12888-023-04603-4

Weinreich, L., Metz, G., Witzel, B., Hermansson, O., Dümig, P., Schulte-Körne, G., & Moll, K. (2023). Evaluating a German learning disorders platform using the RE-AIM framework. *Heliyon*, 10(21), 1-11. https://doi.org/10.1016/j.heliyon.2024.e39968

Supplementary manuscript (currently under review) included in the cumulative dissertation:

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Talks and posters:

Weinreich L. (2021, July 5-9). *Teen cyberbullying: The role of Learning disorders and User Experience Features* [Talk]. ÖGP PhD summer school, Spital am Pyhrn, Austria.

Weinreich L. (2021, September 20-24). Planned study: Response to ostracism in adolescents with learning disabilities and psychiatric comorbidity [Talk]. VIU International PhD Academy, Venice, Italy.

Weinreich, L., Haberstroh, S., Schulte-Körne, G., & Moll, K. (2022, July 4). *The relationship between bullying, learning disorders and psychiatric comorbidity* [Talk]. Wissenschaftliches Symposium anlässlich des 10-jährigen Klinikjubiläums: Forschungstag, Munich, Germany.

Weinreich, L., Metz, G., Witzel, B., Hermansson, O., Dümig, P., Schulte-Körne, G., & Moll, K. (2023, August 28 – September 1). *Evaluating an online platform on developmental learning disorders using the RE-AIM framework* [Poster]. European Conference on Developmental Psychology, Turku, Finland.

Weinreich, L., Metz, G., Witzel, B., Hermansson, O., Dümig, P., Schulte-Körne, G., & Moll, K. (2024, September 16-19). *Evaluating an online platform on developmental learning disorders using the RE-AIM framework* [Poster]. 53rd DGPs Congress/15th ÖGP Conference, Vienna, Austria.

Your contribution to the publications

The contributions to the two publications described below were supervised by Prof. Dr. Gerd Schulte-Körne and PD Dr. Kristina Moll, and done within two different scientific projects.

The first publication included in this dissertation (**paper I)** was part of the project "Machbarkeitsstudie für die Entwicklung und Implementation eines jahrgangsübergreifenden Förderkonzeptes für Kinder mit einer Lese- und Rechtschreibstörung" (in English: "Feasibility study for the development and implementation of a cross-grade support concept for children with reading and spelling disorders"). This project was funded by 'the German Federal Ministry of Education and Research' (BMBF; grant numbers 01GJ1601A and 01GJ1601B).

The second publication included in this dissertation (**paper II**) was part of the project "Verbundvorhaben Evaluation, Implementation und Dissemination der Online-Plattform Diagnostik und Förderung von Kindern mit umschriebenen Entwicklungsstörungen schulischer Fertigkeiten (LONDI-2)" (in English: "A collaborative project for the evaluation, implementation and dissemination of an online platform for diagnostics and support for children with specific developmental disorders of scholastic skills (LONDI-2)"). This project was funded by the BMBF (grant numbers 01GJ2101A and 01GJ2101B).

The appended manuscript (**manuscript**) was supervised by A/Prof. Dr. Bert Timmermans, and done as a part of a research visit to the University of Aberdeen. This visit was funded by the Experimental Psychology Society.

1.1 Contribution to paper I

The contribution to the first paper started with its conceptualization. Specifically, the conception of a detailed research plan after thoroughly exploring a pre-existing large-scale data set, as well as relevant literature. This was followed by discussions with the project supervisors. Thereafter, the contribution was comprised by the formal analysis, writing the original draft, and writing, reviewing, editing and submitting the final manuscript.

1.2 Contribution to paper II

Similarly, the contribution to the second paper started with its conceptualization. Specifically, the conception of a detailed research plan after thoroughly reviewing relevant literature and discussing it

with the project supervisors. This was followed by planning the methodology for data collection, obtaining the necessary software (i.e., Matomo Analytics Software), and pre-registering of the research plan. Thereafter, the contribution was comprised of the investigation (i.e., data collection), data curation, formal analysis, writing the original draft, and writing, reviewing, editing and submitting the final manuscript.

1.3 Contribution to manuscript (Appendix)

Likewise, the contribution to the appended manuscript started with its conceptualization. Specifically, the conception of a detailed research plan after thoroughly reviewing relevant literature and discussing it with the doctoral supervisors. This was followed by planning the methodology for data collection (i.e., a protocol for a systematic review). Thereafter, the contribution was comprised of the investigation, formal analysis, writing the original draft, and writing, reviewing, editing and submitting the final manuscript.

1. Introduction

The goal of this dissertation is to address both the social challenges children and adolescents with learning disorders (LD) and other psychiatric disorders face, and to evaluate a platform designed to support them. Children and adolescents with LD are likely to suffer from social hardship (for a review please see 1). In fact, compared to children without LD, they have a lower number of friends on average, and have a higher tendency to avoid or show disinterest in social connections (2). Bullying is a form of social hardship of particular importance, as it can lead to various negative outcomes such as an increased risk of suicidal ideation (3). Previous research concerning the relationship between LD and bullying has yielded inconsistent results. Some studies provided evidence that LD is a direct bullying risk factor (e.g., leading to social exclusion; 4). Others found that LD are only a risk factor when co-occurring with other psychiatric disorders (e.g., attention-deficit/hyperactivity disorder; 5). **Paper I** aims to clarify the role of psychiatric comorbidity in the association between LD and bullying (6). Adding to that, the **manuscript** is the first to systematically review the impact of social exclusion on adolescents with various psychiatric disorders (7). Complementing these explorations on social hardship, **paper II** addresses an online platform for parents and professionals supporting children with LD (8). Specifically, it concerns the evaluation of LONDI, an online German platform designed to alleviate the academic difficulties and psychological distress experienced by children with LD. Taken together, these papers represent a holistic approach to the topic of learning disorders and psychiatric comorbidity.

2.1 Learning Disorders

Globally, the rate of children meeting the diagnostic criteria for LD ranges between 5-15% (9, 10). This prevalence, as well as the large proportion of children displaying academic underperformance, make LD a source of major global concern (11). Children with LD have deficits in any or all of the following domains: reading, spelling and mathematics (9, 12). Notably, LD are caused by a conjunction of genetic and environmental factors (13). They are not caused by limited academic opportunities, intellectual disabilities, acquired brain injuries, diseases or impaired eyesight or auditory range (9, 10, 12). Children with LD struggle with different scholastic skills (12). Specifically, children with a reading disorder struggle with word recognition leading to inaccurate and influent reading, potentially also leading to problems with reading comprehension; those with a spelling disorder struggle with the ability to spell both on paper and aloud; and those with dyscalculia struggle with basic math skills such as addition and multiplication. Moreover,

children with LD are likely to suffer from psychiatric comorbidity (i.e., the co-occurrence of two or more distinct disorders; 14, 15).

2.2 Learning Disorders and Psychiatric Comorbidity

Children with LD are likely to suffer from both homotypic and heterotypic psychiatric comorbidity (i.e., comorbidity with both disorders from the same and different diagnostic grouping, respectively; 16). In terms of heterotypic comorbidity, children with LD often suffer from both internalizing and externalizing disorders (13). Among German children, the prevalence rates of LD with the internalizing disorders anxiety and depression, and the externalizing disorders attention-deficit/hyperactivity disorder (ADHD) and conduct disorder (CD) are 21%, 28%, 28% and 22%, respectively (17). The co-occurrence of ADHD with LD is of particular importance. Children with ADHD often struggle academically (18). Moreover, they are prone to adopt poor learning behaviors such as reluctance to focus or even attempt challenging tasks, work on their own, or accept help when they need it (19). Additionally, ADHD on its own is a risk factor for other psychiatric disorders such as conduct disorder (20, 18). A noteworthy study by Visser et al. (21) sought to clarify whether ADHD actually confounds or moderates the relationship between academic underperformance and depression, anxiety and conduct disorder. They found that while ADHD symptoms indeed influence this relationship, they do not fully account for it. Thus, the interplay between academic underperformance and different psychopathologies is one that is difficult to untangle.

2.3 Learning Disorders and Bullying

In addition to a higher likelihood of psychiatric comorbidity, some studies have shown that children with LD are also more likely to be involved in bullying (22–24, 5, 25). For example, in a study by Turunen et al. (23), bullying involvement rates were 15% for children with reading difficulties, compared to 9% for those without. But what is bullying exactly? In broad terms, bullying can be described as negative interactions imposed by bullies on victims, which are either individuals or groups perceived as weaker (26). These negative interactions can refer to different forms of bullying. These forms could be physical (e.g., beating), verbal (e.g., cursing), relational (e.g., social exclusion), or relating to property damage (e.g., stealing; 27). In the aftermath of bullying, victims might suffer from various long term negative outcomes, such as increased risk of self-harm and suicidal ideation (28, 29, 3). Unlike victims, bullies frequently enjoy a high

social status among their peers, but are still susceptible to long term negative outcomes (30–32). To efficiently combat the negative outcomes both bullies and victims face, it is important to identify the children most likely to be involved. Such identification is needed for children with LD, owing to the inconsistency in previous findings. Specifically, although some studies have pointed toward LD as a direct bullying risk factor (e.g., 22), others have found that LD are only a risk factor when they co-occur with other psychiatric disorders (e.g., reading disorder co-occurring with ADHD; 5).

The main goal of **paper I** was to examine whether LD are in fact a direct bullying risk factor, or rather one that depends on psychiatric comorbidity (6). To this aim, a sample of nearly 3,000 German third and fourth graders was recruited ($N = 2{,}925$). The children underwent learning assessments for reading, spelling and math skills, as well as a test for nonverbal cognitive abilities (33–37). Moreover, standardized parental questionnaires were used to assess symptoms for two internalizing disorders (i.e., depression and anxiety), and two externalizing disorders (ADHD and CD; 38, 39). To measure bullying involvement, the children filled out a short standardized questionnaire (40). To accomplish the main goal of this study, mediation models were calculated to analyze the relationship between learning disorders and bullying. The model that fit the data best was a mediation model, which showed that internal and external disorders underlie the link between learning skills and bullying involvement. Moreover, the model also showed that although external disorders had a stronger impact than internal disorders, both were statistically significant predictors for bullying involvement ($p < .01$). Compatible with past research (e.g., 23), the results indicated higher bullying involvement rates among boys compared to girls. Notably, this was the first study to demonstrate that LD are not a direct bullying risk factor. Rather, the association between LD and bullying depends on psychiatric comorbidity. Thus, this paper stresses that in addition to academic hardship, children with LD are prone to psychiatric comorbidity, which in turn increases the likelihood of social hardship.

2.4 Psychiatric Disorders and Social Exclusion

Although LD are not a direct bullying risk factor, there is evidence that children and adolescents with LD are more likely to be both socially isolated and excluded (4, 2). One possible reason for this could be the psychosocial difficulties children with LD often experience (e.g., a tendency to receive lower peer status ratings than children without LD; 41). Another possible reason could be psychiatric comorbidity with disorders associated with peer dislike (e.g., ADHD; 42). Moreover, there is evidence from adult studies that

individuals with other psychiatric disorders, such as borderline personality disorder (BPD), are more susceptible to the negative outcomes of social exclusion compared to healthy individuals (for a systematic review, please see 43). This is potentially explained both by problems in forming connections, and by difficulty in coping with rejection related to some psychiatric disorders (e.g., chronic depression; 44). In addition, during adolescence, different aspects contributing to the ability to regulate the distress caused by social exclusion are still developing (e.g., social emotional processing; 45). Furthermore, adolescents place great gravity on peer relationships and status (46, 47). Thus, taken together, it is unsurprising that during adolescence, individuals with psychiatric disorders are particularly susceptible to the negative outcomes of social exclusion compared to healthy adolescents (e.g., 48).

Unlike other forms of bullying like physical or verbal, social exclusion is relational, and characterized by impairments of victims' status and relationships (27). These impairments, according to the evolutionary perspective, could lead to reduced social support, which then negatively impacts survival chances (49). Furthermore, social exclusion could lead to lower self-esteem and various other negative outcomes, ranging from lower prosocial tendencies to outright violent behavior (50–53). In experimental settings, social exclusion is often simulated with the Cyberball paradigm (54). Cyberball is an online ball passing game, in which participants can be made to feel socially excluded or included by being either ignored or getting the ball passed to them, respectively. Nevertheless, most social exclusion experiments focus on typically developed adolescents (55). At present, experimental investigations of social exclusion among adolescents with LD in particular, and psychiatric disorders in general, have yet to be systematically reviewed; and the existing experiments are scarce compared to those with typically developed populations (56).

The **manuscript** examines social exclusion among adolescents with various psychiatric disorders (7). The main goal of the **manuscript** was to shed light on the impact of social exclusion on adolescents with either LD or any other psychiatric disorders, and to examine group differences with typically developed adolescents. To this aim, experiments were systematically reviewed in line with the PRISMA reporting guidelines (57). The initial search resulted in 174 experiments. After deduplication, screening and eligibility evaluations, the final sample included 12 experiments.

Notably, none of the experiments featured adolescents with either an isolated or a comorbid LD, and only one study used a paradigm with realistic features (58). Among the 12 included experiments, the most researched psychiatric disorder was depression featured in seven experiments (44, 59–64). The other five studies featured clinical groups with autism spectrum condition (65, 66) and with various other disorders

(e.g., BPD; 67, 68, 58). Future research is needed to evaluate the impact of social exclusion on adolescents with a wider range of disorders and psychiatric comorbidity. For example, CD was not featured in any of the experiments. CD, which often co-occurs with LD (17) could be an interesting disorder in the context of social exclusion, as it is characterized among other things with problems in conforming with social norms and aggressive tendencies (9). Moreover, only one study used a realistic paradigm that simulates real-life social exclusion in an instant messaging application many adolescents use (i.e., WhatsApp; 58). Further studies examining the impact of social exclusion among adolescents with psychiatric disorders using real life situations could be very insightful.

All 12 included experiments found that the impact of social exclusion on adolescents with psychiatric disorders differs from that of inclusion. Only 4 experiments using behavioral measurements revealed group differences via self-reported measurements such as the Needs-Threat-Scale, assessing threats to fundamental needs (e.g., the need for meaningful existence; 65, 67, 60, 66). These studies pointed toward increased negative emotional responses among adolescents with psychiatric disorders. Group differences were not clear among 5 other experiments using behavioral measurements (44, 63, 68, 58, 64). This lack of clarity was due to various reasons. For example, having no baseline measurements, which made it impossible to determine if differences were due to social exclusion or pre-existing developmental differences. Inversely, all 8 experiments using fMRI measurements revealed group differences (44, 59–63, 66, 68). Taken together, these experiments provide inconclusive and conclusive evidence to behavioral and neurobiological group differences, respectively.

2.5 Support for Children with Learning Disorders

Both **paper I** (6) and the **manuscript** (7) explore the social hardships children and adolescents with LD and other psychiatric disorders face, but not means to support them. The global rise in digitalization has made online support platforms broadly accessible (69). One such platform is LONDI, a German platform developed for those supporting children with both isolated and comorbid LD. The platform is freely available online (www.londi.de). It was designed for five user groups: parents, teachers, school psychologists, social workers and learning therapists. It contains two main components: user specific information and a help system. The informational component is tailored to the needs of each user group. An example for information tailored for parents' needs is a section on to how to help their children with homework at home. An example for information tailored for learning therapists, in contrast, is a section on how to adapt

a therapy plan for children with psychiatric comorbidity. The help system component is an algorithm-based tool for learning therapists and school psychologists. It can be used to get diagnostic and intervention recommendations for each child, based on their specific learning profile. With these components, the goal of the LONDI platform is to alleviate both the academic difficulties and the psychological distress children with LD face.

The goal of **paper II** was to evaluate LONDI's actual impact (8). The evaluation focused on the learning therapist user group, the pages designed for them, and the help system. The theoretical framework used in this evaluation was RE-AIM (70), and four of its dimensions: Reach, Adoption, Implementation and Maintenance. Reach refers to the proportion of a targeted user group an intervention manages to reach; Adoption to the proportion of a targeted user group that adopts an intervention; Implementation to the way an intervention is implemented in natural settings; and Maintenance to the way an intervention is practiced over time. RE-AIM was chosen for this evaluation as it is well-established (71) and has been used to evaluate multiple online platforms related to education and health (e.g., 72–75).

Results were obtained for each of the above-mentioned RE-AIM dimensions. In terms of *Reach*, a questionnaire filled by 496 users revealed that the proportion of learning therapists was much larger than their proportion in Germany (17.53% vs. <0.001%), indicating that the platform reached its targeted user group. In terms of *Adoption*, an additional questionnaire filled by 150 users revealed that they intend to adopt the help system, and this was predicted by how practical they found it. In terms of *Implementation*, web analytics' data for 8,459 visits that occurred between 01.01.23 and 30.06.23, indicated that the platform was not used as predicted (e.g., more time was spent on certain pages than expected). However, these results are not necessarily a bad indication, since the implementation benchmarks (e.g., for abandonment rates) were taken from marketing research. Future research is needed to evaluate implementation using different parameters, such as average reading times (76). In terms of *Maintenance,* the number of users increased by 64% after three months (i.e., 3.202 vs. 5,257 users). At the same time, the average amount of time users spent on the platform decreased. This pattern could be explained by the fact that over time, the number of smartphone users increased, and smartphone visits are typically shorter than desktop visits (77). Future efforts are needed to ensure the platform is optimally compatible for smartphones. All in all, these results showed that the platform reached learning therapists, and that they intend to use it to support children with LD.

2.5 General Discussion

In addition to academic hardship, children with LD often struggle psychosocially (41). As shown in **paper I** (6), children with LD and psychiatric comorbidity are at a higher risk of bullying involvement. In line with the findings of Turunen et al. (78), it appears that while LD on their own do not pose as a major risk factor toward bullying involvement, when they co-occur with other psychiatric disorders (e.g., externalizing disorders) the risk increases. Future research could further explore group comparisons to clarify whether it is indeed the combination of LD and psychiatric comorbidity, or rather solely the co-occurring disorders that increase the risk of bullying involvement. Importantly, when asking a child if they are involved in bullying, it is advisable to not ask them directly, but rather ask them about specific behaviors they might be involved in (e.g., rumor spreading, vandalization, hitting, etc.). This could contribute to a more accurate understanding of the nature and magnitude of the situation (79). Given the wide array of potential negative outcomes resulting from bullying involvement (e.g., increased risk to attempt suicide; 80), it is of utmost importance for both parents, teachers and health care professionals to both identify and support children at risk (81).

Adding to **paper I** (6), the **manuscript** (7) focused on a specific form of bullying children and adolescents with LD are susceptible to, namely, social exclusion (4). Specifically, a systematic review was conducted to explore the impact of social exclusion on adolescents with LD and/or any other psychiatric disorders. None of the experiments that met the review's inclusion criteria sampled adolescents with either isolated or comorbid LD. Thus, the review underlines the need for future research testing the impact of social exclusion on adolescents with a wider range of disorders, including LD. Nevertheless, the review's results are still valuable for LD research, as LD often co-occur with other psychiatric disorders (14). Overall, the review revealed that adolescents with psychiatric disorders are particularly susceptible to the negative outcomes resulting from social exclusion. Furthermore, it revealed conclusive neurobiological evidence, pointing toward differences in brain activation in adolescents with vs. without psychiatric disorders. Notably, the increase in digitalization in recent years has made online support platforms widely available (82). At the same time, however, this increase has also contributed to a steady increase in cyberbullying prevalence (83). Compared to traditional bullying, cyberbullying can happen at any time (e.g., outside of school), and it is harder for parents and professionals to notice it (81). For example, it is easier to notice when a child is being socially excluded at a playground than when they are excluded from a group chat on

their smartphone. In addition to being informed on a child's bullying involvement, parents and professionals should guide adolescents on practices of safe internet use (81). Moreover, socially excluded adolescents should be screened for psychiatric disorders to ensure that they are receiving appropriate support (81).

For those supporting children with LD, the LONDI platform was developed and its evaluation was the goal of **paper II** (8). Overall, the evaluation showed that the platform managed to both reach targeted users and that they intend to use it again. This is notable considering that other relevant online resources in German do exist, such as the website of the Federal Association for Dyslexia and Dyscalculia (84). The LONDI platform's unique combination of evidence-based information customized to different user groups, as well as its help system seem to be valuable to its users, as indicated for example by an increase in the number of users over time. In addition to questionnaires, this evaluation tracked online usage, which led to a sample size of over 8,000 participants, and multivariable data on online user behavioral patterns. In recent years, the number of theory-based platform evaluations that use similar online measurements has been on the rise (e.g., 85). However, these online measurements (i.e., web analytics) are still mostly used for commercial purposes (77). Future research using web analytics is needed to further examine how the platform is being implemented. For example, by comparing the time spent on different pages according to the type of device used (e.g., smartphone). Moreover, web-analytics could be used in other online contexts relating to children with LD, for example to evaluate the implementation of computer-game-based interventions.

To conclude, this dissertation combines two different aspects. The first aspect concerns the social challenges children and adolescents with LD and other psychiatric disorders face, and the second concerns an evaluation of a platform system designed to support them. Although the included papers vary in topic and methodology, they all contribute to furthering the field of learning disorders and psychiatric comorbidity research.

3. Summary (in English)

The goal of this dissertation is to evaluate both the social hardships faced by children and adolescents with learning disorders (LD) and other psychiatric disorders, as well as a platform for those supporting them. Worldwide, the prevalence of children meeting diagnostic criteria ranges from 5 to15%. This prevalence, along with the increasing number of children displaying academic underperformance, makes LD a major public concern. Children with LD are prone to psychiatric comorbidity (e.g., a reading disorder co-occurring with depression). Additionally, some evidence suggests that they are more likely to be involved in cyber/bullying. The goal of **paper I** was to examine the association between LD and bullying. Specifically, to determine whether the association is direct or mediated by psychiatric comorbidity. The results support the latter, suggesting that children with LD are more likely to suffer from psychiatric comorbidity, which, in turn, increases their risk of bullying involvement.

Although LD are not a direct risk factor for bullying, there is some evidence indicating that children and adolescents with LD are more likely to be socially excluded. Social exclusion, unlike other bullying forms, is relational and pertains to impact on victims' status and peer interactions. The goal of the **manuscript** was to systematically review experimental investigations of social exclusion among adolescents with LD and other psychiatric disorders. The focus on adolescence was chosen as it is a developmental stage during which individuals are particularly susceptible to the potential negative consequences caused by social exclusion (e.g., negative emotional state). Notably, a systematic search yielded 12 relevant experiments, none of which featured LD. The most studied disorder was depression, appearing in seven experiments. While only some of the experiments using behavioral measurements found group differences between adolescents with vs. without psychiatric disorders following social exclusion, all the experiments using neurobiological measurements reported group differences. This points toward altered neural reactivity during social exclusion among adolescents with psychiatric disorders. However, further experiments investigating the impact of social exclusion on adolescents with a broader range of psychiatric disorders, including LD, are needed.

In addition to the above-mentioned papers, the goal of **paper II** was to evaluate LONDI, a platform designed for various user groups supporting children with LD: parents, learning therapists, teachers, school psychologists, and social workers. The platform offers customized information for each group and features an algorithm-based help system for mental health professionals. This evaluation focused on learning therapists, using RE-AIM as its theoretical framework. Results showed that the platform successfully reached learning therapists, who indicated an intention to adopt its help system. Interestingly, the platform was implemented differently than expected (e.g., users spent more time than expected on certain pages but not others), highlighting the need for further research to explore implementation. Moreover, usage patterns were not maintained. While the number of users increased over time, so did the proportion accessing the platform via smartphone vs. desktop. At the same time, the average time users spent on the platform decreased, aligning with the observation that users tend to spend less time online when using smartphones. Overall, the platform appears to provide valuable support to learning therapists. However, further efforts are needed to evaluate its implementation and to prioritize compatibility for smartphone vs. desktop. Although this paper differs considerably from the others, all contribute to advancing both the understanding and means of supporting children and adolescents with learning disorders and psychiatric comorbidity.

4. Zusammenfassung (deutsch)

Das übergeordnete Ziel dieser Dissertation ist es, soziale Probleme von Kindern und Jugendlichen, die sowohl an Lernstörungen als auch anderen psychiatrischen Erkrankungen leiden, zu untersuchen. Zusätzlich soll eine Plattform zum Thema Lernstörungen evaluiert werden, die unterschiedlichen Zielgruppen dabei helfen soll, betroffene Kinder und Jugendliche zu unterstützen. Die weltweite Prävalenz von Kindern, die die Diagnosekriterien für das obengenannte Szenario erfüllen, liegt bei 5 bis 15 %. Dieser Anteil an der Gesamtbevölkerung und die allgemein zunehmende Zahl von Kindern mit schulischen Defiziten machen Lernstörungen zu einem wichtigen öffentlichen Anliegen. Kinder mit Lernstörungen haben ein allgemein erhöhtes Risiko für psychiatrische Komorbiditäten (Beispiel: Leseschwäche einhergehend mit Depression). Zusätzlich gibt es Hinweise darauf, dass Kinder mit Lernstörungen mit höherer Wahrscheinlich in Mobbing beziehungsweise Cybermobbing involviert sind. **Paper I** hatte vor diesem Hintergrund zum Ziel, den Zusammenhang zwischen Lernstörungen und Mobbing zu untersuchen. Insbesondere sollte festgestellt werden, ob es einen direkten Zusammenhang zwischen Lernstörungen und Mobbing gibt, oder ob dieser Zusammenhang über psychiatrische Begleiterkrankungen vermittelt wird. Die Ergebnisse deuten auf Letzteres hin. So lässt sich zum jetzigen Zeitpunkt annehmen, dass Kinder mit Lernstörungen mit erhöhter Wahrscheinlichkeit an psychiatrischen Begleiterkrankungen leiden, die wiederum das Risiko für Mobbing erhöhen.

Obwohl Lernstörungen demnach noch keinen direkten Risikofaktor für Mobbing darstellen, gibt es Hinweise darauf, dass Kinder und Jugendliche mit Lernstörungen eher von sozialer Ausgrenzung betroffen sind. Soziale Ausgrenzung ist dabei im Gegensatz zu anderen Formen von Mobbing relational und bezieht sich begrifflich auf die Auswirkungen auf den Status der Betroffenen und ihren Kontakt zu Gleichaltrigen. Im Rahmen von das **manuscript** wurde daher ein systematisches Review durchgeführt, das die aktuelle Befundlage zu sozialer Ausgrenzung von Jugendlichen mit Lernstörungen und anderen psychiatrischen Erkrankungen auf Basis experimenteller Untersuchungen ermitteln sollte. Jugendliche wurden dabei als Schwerpunkt gewählt, da die Pubertät eine Entwicklungsphase darstellt, in der Personen besonders empfänglich für negative Konsequenzen sozialer Ausgrenzung (Beispiel: negative Gefühlszustände) sind. Im Zuge des systematischen Reviews wurden insgesamt 12 relevante Experimente identifiziert, von denen jedoch keines Lernstörungen adressiert. Die hingegen am häufigsten untersuchte Erkrankung war Depression, die in sieben Experimenten thematisiert wurde. Auf Basis von Verhaltensmessungen konnten nur einzelne Experimente Unterschiede zwischen Jugendlichen mit und ohne psychiatrische Erkrankungen im Anschluss an soziale Ausgrenzung nachweisen. Demgegenüber wurden in allen Experimenten Gruppenunterschiede auf Basis neurobiologischer Messungen festgestellt. Dies deutet auf eine veränderte neuronale Reaktivität bei Jugendlichen mit psychiatrischen Erkrankungen bei sozialer Ausgrenzung hin. Insgesamt sind jedoch weitere Experimente notwendig, um die Auswirkung sozialer Ausgrenzung auf Jugendliche mit einem breiten Spektrum psychiatrischer Erkrankungen, einschließlich Lernstörungen, zu untersuchen.

Abschließend zu den oben erwähnten Publikationen wurde in **Paper II** eine Plattform (LONDI) evaluiert, die entwickelt wurde, um unterschiedlichen Zielgruppen Informationen und Hilfe bei der Unterstützung von Kindern mit Lernstörungen bereitzustellen. Zu den angesprochenen Zielgruppen zählen Eltern, Lerntherapeuten, Lehrkräfte, Schulpsychologen und Sozialarbeiter. Die Plattform beinhaltet zielgruppenspezifische Informationen und verfügt zudem über ein auf einem Algorithmus basierenden Unterstützungssystem für Fachkräfte im Bereich der psychischen Gesundheitsversorgung. Die Evaluierung konzentrierte sich auf Lerntherapeuten und basierte auf RE-AIM als theoretischem Bezugsrahmen. Die Ergebnisse zeigten einerseits, dass die Plattform diese Zielgruppe erfolgreich erreichte und dabei von Seiten der Lerntherapeuten die Absicht gezeigt wurde, das Unterstützungssystem verwenden zu wollen. Anderseits wurde

deutlich, dass die Plattform häufig anders genutzt wurde als ursprünglich angenommen (Beispiel: Nutzer verbrachten mehr Zeit auf bestimmten Seiten als auf anderen), was die Notwendigkeit weiterer Forschung in der Anwendung der Plattform unterstreicht. Zusätzlich veränderte sich das Nutzungsverhalten. So stieg etwa gleichzeitig mit der Gesamtzahl der Nutzer auch die Zahl der derjenigen Nutzer, die die Plattform über Smartphones anstatt von Desktop-Geräten nutzten. Gleichzeitig verringerte sich jedoch auch die durchschnittliche Verweildauer der Nutzer auf der Plattform, was sich vermutlich durch die generell kürzere Verweildauer von Smartphone-Nutzern auf Webseiten erklären lässt. Insgesamt betrachtet scheint die Plattform ein wertvolles Unterstützungsangebot für Lerntherapeuten darzustellen. Dennoch sind weitere Bemühungen notwendig, um die Anwendung der Plattform umfassender zu evaluieren und ihre Kompatibilität für Smartphone-Nutzer (gegenüber Desktop-Nutzern) zu optimieren. Obwohl sich diese Publikation damit thematisch und methodisch von den eingangs erwähnten Publikationen unterscheidet, tragen dennoch alle in der Summe sowohl zu einem besseren Verständnis von Lernstörungen und psychiatrischen Begleiterkrankungen als auch der Unterstützung von betroffenen Kindern und Jugendlichen bei.

5. Paper I

BMC Psychiatry

RESEARCH Open Access

The relationship between bullying, learning disorders and psychiatric comorbidity

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Abstract

Background Both learning disorders and bullying are major sources of public concern. Children with learning disorders often suffer from social rejection, potentially rendering them more susceptible to bullying involvement. Bullying involvement leads to a higher risk towards developing various problems including self-harm and suicidality. Past research on whether learning disorders are childhood bullying risk factors yielded inconsistent results.

Methods The current study used path analyses on a representative sample of 2,925 German 3rd and 4th grades to examine whether learning disorders are a direct bullying risk factor, or whether their impact depends on psychiatric comorbidity. More so, the current study sought to examine whether associations differ between children with and without learning disorders, compare different bullying roles (i.e., only victim, only bully, or bully-victim), compare gender, and control for IQ and socioeconomic status.

Results Results indicated that learning disorders are not a direct but rather an indirect childhood risk factor for bully-victim involvement, depending on psychiatric comorbidity with internalizing or externalizing disorders. Regarding the comparison between the samples of children with and without learning disorders, an overall difference and a difference in the path between spelling and externalizing disorders emerged. No difference for different bullying roles (i.e., only victim, only bully) emerged. Negligible differences emerged when IQ and socioeconomic status were controlled. An overall gender difference emerged, compatible with past research, indicating higher bullying involvement among boys compared to girls.

Conclusion Children with learning disorders are at a higher risk of having psychiatric comorbidity, which in turn renders them at a higher risk of bullying involvement. Implications for bullying interventions and school professionals are deduced.

Keywords Childhood bullying, Learning disorders, Psychiatric comorbidity, Path modeling

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Purpose

The main purpose of the current study was to find out whether children with learning disorders are more susceptible to bullying involvement, or if such susceptibility depends on psychiatric comorbidity. Thus, shedding light on the inconclusive nature of the results of previous studies done in this realm. Additional purposes included the comparison between children with and without learning disorders, different bullying roles (i.e., only victim, only bully, bully-victim), gender, and controlling for IQ and socioeconomic status.

Background

Learning disorders (LD) can be broadly defined as persisting poor academic skills and outcomes according to The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5; 1). LD symptoms include deficits in: reading (i.e., accuracy, fluency and/or reading comprehension); spelling; and basic math skills such as calculation and fact retrieval [1]. Notably, these difficulties are not accounted by a lack of motivation or access to education, intellectual disabilities, poor vision or poor hearing [1, 2]. LD develop due to both environmental and genetic factors [3]. Heritability rates range between 50 and 70% for reading disorder (i.e., dyslexia), and between 40 and 60% for math disorder (i.e., dyscalculia; 3, 4, 5).

Notably, LD are a major source of public concern worldwide [6]. Alarmingly, up to 40% of North American children read below grade level [7], and 5–15% of children worldwide fulfill diagnostic criteria for LD [1, 2]. Specifically, roughly 4–17% of children fulfill diagnostic criteria for reading disorder; 5–7% for spelling disorder; and 2–13% for math disorder [7–11].

Additionally, children with LD are prone to psychiatric comorbidity [12]. Angold et al.[13] define psychiatric comorbidity as the co-occurrence of two or more distinguished disorders. Two types of comorbidities are distinguished: those belonging to the same diagnostic grouping (i.e., homotypic comorbidity); or to different diagnostic grouping (i.e., heterotypic comorbidity). Correspondingly, LD may co-occur both with one another and with other disorders [1].

Remarkably, comorbidity rates for LD are not only high for homotypic comorbidity (e.g., ranging between 17% and 70% for a comorbid reading and math disorder; 11) but also for disorders from very different diagnostic categories, such as between reading disorder and attention-deficit/hyperactivity disorder (i.e., ADHD; 14, 15). For example, Visser et al. [15] found comorbidity rates of 21% for LD and anxiety disorder; 28% for LD and depression; 28% for LD and ADHD; and 22% for LD and conduct disorder.

Furthermore, children with LD (with or without co-occurring disorders) are prone not merely to academic hardship, but also to truancy, early dropout and social hardship [16, 17]. For example, roughly 25–30% of children with LD suffer from social rejection, compared to 8–16% of children without LD [18]. In turn, this rejection renders children with LD less socially protected, and thus more susceptible to being victims of bullying acts [17].

Bullying is defined as imposed aggressive acts, inflicted by aggressors towards victims, under a power imbalance [19]. Gladden et al. [19] distinguish between two *modes* of bullying: direct – happens in the presence of the victim (e.g., pushing); and indirect – happens in the absence of the victim (e.g., rumor spreading). Furthermore, they distinguish between four *types* of bullying: physical – via physical force (e.g., kicking); verbal – via oral or written discourse (e.g., taunting); relational – via impairment of one's reputation and social contact (e.g., excluding); damage to property – via stealing or vandalizing (e.g., trashing). Thus, bullying can be inflicted in many forms, negatively impacting everyone involved (i.e., victims of bullying acts, bullies, and bystanders; 20).

Notably, both worldwide and in Germany, bullying is a major source of public concern [21]. About 16% of German students, amongst them boys more so than girls, have been involved in bullying [21]. These estimates are even higher, reaching up to 25%, among German children and young adults undergoing psychotherapy [22]. This is alarming, as both being a victim of bullying and being a bully are associated with behavioral and emotional problems.

Victims of bullying acts are characterized by impaired relations with peers, teachers and parents [23]. Additionally, as victimization increases, they become more prone to pessimism, depressive symptoms, lower popularity, somatic complaints, anxiety, self-blame and murderous ideation and behaviors [23–25]. Moreover, victims are at a higher risk towards developing: psychosomatic disorders (e.g., migraines; 26), internalizing disorders (e.g., depression; 27), educational impairments (e.g., test underperformance; 19), psychosis in late adolescence [28], and a variety of long-term problems persisting throughout adulthood, such as self-harm and suicidality [29–32]. Interviews also reveal that victims constantly feel fearful of being bullied again, insecure, isolated, and angry [33].

Parallelly, as victims, *bullies* are characterized by impaired relations with peers, teachers and parents [23]. Additionally, as bullying involvement increases, they become more prone to pessimism, depressive symptoms and murderous ideation and behaviors [23, 25]. Moreover, bullies are also at a higher risk towards developing psychosomatic disorders [26], and psychosis in late adolescence [28]. However, unlike victims, bullies often enjoy popularity and friendships [23, 24].

Previous research on victims of bullying acts revealed the following prominent childhood bullying risk factors: intelligence (e.g., low IQ), high body mass index (i.e., BMI; e.g., obesity), internalizing and externalizing disorders (e.g., anxiety and ADHD, respectively), physical disabilities, socioeconomic status (i.e., SES; e.g., low income), low maternal support, identification as lesbian, gay, bisexual, transgender and related communities (i.e., LGBTQ+), immigrational background, minority religious affiliations, and intersectionality [27, 34–38].

Nonetheless, previous research on other childhood bullying risk factors, and namely having LD, has yielded inconsistent results. Some studies reported an association between LD and victimization [39–42]. Others found that LD was only related to victimization when associated with comorbid disorders, such as ADHD [43], or that LD was unrelated to victimization, but rather other controlled factors such as prior history of victimization emerged as risk factors [44]. Similarly, whereas some studies reported an association between LD and bullying perpetration [45], others found that LD was unrelated to bullying perpetration, but rather other controlled factors such as gender emerged as risk factors [46].

There are several potential explanations for these inconsistent findings:

One possible reason is that previous research investigating LD as a childhood bullying risk factor did not always take psychiatric comorbidity into account. The few existing studies found that children with LD and psychiatric comorbidity (e.g., LD and ADHD) are at a higher risk of victimization [42], and of being bullies and bully-victims [47, 48]. However, these studies did not examine all bullying roles (i.e., only victim, only bully, or bully-victim), or did not examine the effect of difficulties in different learning domains (i.e., reading, spelling, and math). Controlling for psychiatric comorbidity is important as it often co-occurs with LD [11] and as some disorders (e.g., anxiety) have been shown to be childhood bullying risk factors [29].

A second possible reason is that the research was based on very different samples, namely clinical samples, typically developing children, and representative samples, covering the whole distribution of learning skills. For example, Klomek et al. [43] used a sample including only children in general education, whereas Blake et al. [44] also included children in special education. It is possible that the predictive patterns might differ among children with LD, belonging to the lower end of the learning distribution, compared to typically developing children or a sample representing the whole distribution.

A third possible reason is that previous studies did not always take both aspects of bullying into account, namely bullying and victimization. For example, Blake et al. [44] measured only if LD is associated with being a victim, but not with being a bully. Nevertheless, some children, and those with ADHD in particular, are prone to be both bullies and victims (i.e., bully-victims; 17, 37). More so, ADHD related behavior, such as hyperactivity, along with social difficulties, are linked to both conduct disorder and lower popularity [49, 50]. Lower popularity among children with ADHD, in turn, leads to higher rates of victimization [37]. Such victimization may result in being a bully as a form of resistance, in which the child bullies not proactively but rather as a backlash [51]. This bully-victim duality can be explained by the term "negative feedback loop" coined in this context by Simmons and Antshel [52]. This negative loop puts bully-victims at a higher risk towards developing both internalizing and externalizing co-occurring disorders [37, 51, 53].

Finally, the inconsistent results might be a consequence of not taking other potentially relevant factors into account. Notable factors that could affect the association between LD and bullying are gender, IQ, and socioeconomic status (SES). The few existing studies on LD as a bullying risk factor that did control for gender, yielded inconsistent results. While Klomek et al. [43], Rose et al. [46] and Turunen et al. [40] found higher bullying involvement rates for boys compared to girls, Blake et al. [44] found no gender differences. Controlling for gender is important as it could influence bullying involvement overall and involvement in specific bullying roles. For example, there is some evidence that girls are more likely to be victims [46]. With respect to IQ and SES, both have emerged as prominent bullying risk factors in previous research (e.g., 34), but the association between LD and bullying and the role of IQ and SES in explaining this relationship has yet to be determined.

The current study sets to investigate the role of LD and psychiatric comorbidity as childhood bullying risk factors in a representative sample of 2,925 German 3rd and 4th graders. Moreover, the study addresses the possible reasons for the inconsistent findings from previous research reviewed above by: Firstly, taking into account co-occurring difficulties, namely both internalizing (i.e., anxiety and depression) and externalizing disorders (i.e., ADHD and conduct disorder); Secondly, analyzing both a representative sample as well as comparing children with and without LD; Thirdly, taking bullying role duality into account (i.e., being both a bully and/or a victim); and fourthly, taking gender, IQ and SES into account. That is, a model was built with learning skills (i.e., reading, spelling and math skills) as exogenous variables, IQ, SES, internalizing and externalizing disorders as the endogenous variables and bully-victim involvement as the outcome variable.

Aim

The methods employed in the current study aim to answer the following research questions: [1] Is there a direct link between LD/learning skills and childhood bullying, or does the association depend on other co-occurring psychiatric disorders? [2] Do the associations differ when comparing children with and without LD? [3] Do these associations differ when examining either being both a bully and a victim compared to only being a victim or a bully? [4] Do these associations differ for boys compared to girls, and do these associations differ when taking IQ and SES into account?

Methods

Participants

Recruitment for the current study targeted families with children in 3rd and 4th grade residing in two different federal states in Germany: Hesse and Bavaria. In Hesse, families were invited via the Ministry of Education and Cultural Affairs (N=25,000), and in Bavaria, families were invited via local registration offices (N=27,734). Overall, 52,734 randomly chosen families were invited and, among them, 4542 families agreed to participate. These recruitment invitations were coordinated by two collaborating institutions from the above mentioned German federal states, respectively: The Leibniz Institute for Research and Information in Education (DIPF) in Frankfurt; and The Clinic for Children and Adolescent Psychiatry, Psychosomatics and Psychotherapy (KJP) in Munich.

This initial sample size (N=4542) was reduced due to the following applied exclusion criteria: participants did not complete all test items or questionnaires; parents reported in an open-ended question that their child had either a neurological disease, a hearing or a visual problem, or a chromosomal defect; children had an IQ below or equal to 70. Furthermore, to avoid statistical dependence, data for one sibling per sibling-pair was excluded randomly. The resulting final sample size was N=2,925, with a mean age of 9.72 years (SD=7.19 months; range 8.08–11.67), and was constituted of: 52% (n=1520) boys; 48% (n=1405) girls; 47.5% (n=1390) 3rd graders; 52.5% (n=1535) 4th graders.

Among the 2,952 participants of the final sample, 13% (n=373) had LD. Diagnostic criteria for LD (i.e., reading, spelling and/or math disorder) were based on the German clinical diagnostic guidelines[54, 55] and in accordance with the recommendation of the DSM-5 [1]. In order to receive a diagnosis of LD, performance had to be at least 1.5 standard deviations (SD) below the sample's grade-specific mean in at least one of the different standardized academic tests (assessments detailed below under "Children's assessments"). Notably, the guidelines also recommend a less stringent criterion of -1 SD, but only when other information supporting the existence of LD is available (e.g., clinical assessments), which was not the case in the current study.

Data collection

Data for the current study was collected by the collaborating institutions as part of a larger study that explored children's comorbid LD, whilst taking into account numerous familial and environmental factors. Specifically, data were collected via a web-based application (i.e., app) assessing children's academic skills and psychopathological profile. The app was developed by a German software company (i.e., Meister Cody), and was downloaded and installed by all invited families using a login code. After logging in, parents were asked to give informed consent, in accordance with the Declaration of Helsinki. Priorly, approval was obtained from the ethics committees in both collaborating institutions.

Participants were instructed to install the app on either a smartphone or tablet within eight weeks after receiving the invitation to take part in the study, and complete various tests and questionnaires. Children had to complete the following tests and questionnaires: academic tests assessing reading, spelling and math skills; a test measuring nonverbal cognitive abilities; four questionnaires assessing their psychopathological profile; and a questionnaire about bullying involvement. These had to be completed in four separate days (i.e., each day composed a session). An additional fifth session, in which children were asked to complete a piloted spelling test was optional and not part of the current analysis. Each session lasted roughly 30–45 min. To avoid tediousness and encourage engagement, sessions were gamified and embedded in a story about a magician. Parents had to complete various questionnaires about their children in the course of one session. For the current study, the explored data obtained from participating children was composed of academic tests, a test measuring nonverbal cognitive abilities (IQ), and a bullying questionnaire. Parallelly, the explored data obtained from participating parents was composed of a psychopathological profile questionnaire, and a familial and environmental factors questionnaire.

Measures

Children's assessments

Reading skills were assessed using the Würzburger silent reading test – revised (WLLP-R; 56). Retest-reliability obtained from the test manual is: $r_{tt} = 0.82$ for 3rd graders, and $r_{tt} = 0.80$ for 4th graders. The test is designed to assess word reading fluency. It is composed of 180 items, and is suitable for children from 1st -4th grade. Each item is composed of a word and four images. Children had to read the word and identify the image that matches the word as fast as possible. In the course of five allocated

minutes, children had to match as many items as possible. The relevant score is the number of items processed correctly within the time limit (max. score = 180).

Spelling skills were assessed using the long version of the Weingartener spelling test for basic vocabulary for 3rd graders (WRT 3+; 57) and 4th graders (WRT 4+; 58). Retest-reliability obtained from the test manual is: $r_{tt} > 0.92$ for 3rd graders, and $r_{tt} > 0.93$ for 4th graders. The test is designed to assess spelling accuracy. The WRT 3+ is composed of 55 items, and the WRT 4+ of 60 items. During the test, children had to fill in dictated words that were presented in a sentence frame. The relevant score is the number of correctly spelled words (max. score = 55 and 60 for 3rd and 4th grade, respectively).

Math skills were assessed using the arithmetic scale of the Cody math test (CODY-M 2–4; 59). Retest-reliability obtained from the test manual of the arithmetic scale is $r_{tt} = 0.85$. The arithmetic scale is composed of four subtests: addition (7 items), subtraction (7 items), multiplication (4 items), and place holder (4 items). The test is suitable for children from 2nd -4th grade. During the test, children were presented with audible instructions and instructed to solve the written questions by typing in the correct answer (e.g., 57 − 23 = __). The relevant score is the number of correct answers (max. score = 22).

Nonverbal cognitive abilities (i.e., IQ) were assessed using the Culture Fair Intelligence Tests (CFT 20-R; 60). Retest-reliability obtained from the printed test manual is: $r_{tt} > 0.80$. The test is suitable for children from ages 8.5-19.11. For the current study, three of the four subtests that were compatible for online usage (i.e., sequences of drawing, classifications and matrices) were used, each composed of 15 items. During the test, children were presented with tasks varying in complexity, and instructed to recognize figural relationships and solve logical problems within a time limit (4, 4 and 3 min, respectively for the above-mentioned subtests). The relevant score is the number of correct answers (max. score = 45).

Bullying involvement was assessed using the short German version of the revised Olweus bully/victim questionnaire (OBQ; 61, 62). The questionnaire's reliability measure obtained from the test manual is: Cronbach's alpha = 0.84. The test is designed to assess the frequency of bullying involvement both as a bully and as a victim (e.g., "I called a classmate an ugly name", "I have been made fun of and teased in a mean way"). The test is composed of 18 items: 9 assessing bullying perpetration; and 9 assessing victimization. Two items were excluded because of their high complexity level (i.e., "I called a classmate an ugly name because of the color of their skin or where they came from", and "I was called an ugly name because of the color of my skin or where I came from"). Thus, the final test was composed of 16 items: 8 assessing bullying perpetration and 8 assessing victimization. Since two of the options on the five-point Likert scale were too similar for the 3rd and 4th graders that participated (i.e., "two or three times a month" vs. "once a week"), they were merged. Thus, items were scored on a four-point Likert scale (scores ranged between 0 and 3). The relevant scores are the z-standardized summed scores for bullying perpetration (based on the 8 bullying perpetration items), victimization (based on the 8 victimization items), and bully-victim involvement (based on all 16 items). In order to clearly differentiate between the different roles, z-scores larger than 1 (SD > 1) indicated either bullying perpetration, victimization or bully-victim involvement, and scores equal or lower than 0 (i.e., the mean) indicated either no bullying perpetration, no victimization or no bully-victim involvement.

Parents' assessments

Psychopathological profiles were assessed using three scales from a standardized parental questionnaire, the diagnostic system for mental disorders according to ICD-10 and DSM-IV, for children and adolescents (DISYPS-II; 63). The three scales assess children's symptoms of depression, conduct disorder, and ADHD. The reliability measures obtained from the test manual are: Cronbach's alpha = 0.89, 0.89 and 0.94, respectively for the above-mentioned scales. The three scales comprise 87 items: 42 items about depression; 25 items about conduct disorder, which included nine items about oppositional-aggressive behavior and 16 about antisocial-aggressive behavior; and 20 items about ADHD, which included nine items about inattention, seven about hyperactivity, and four about impulsivity. Items were scored on a four-point Likert scale (scores ranged between 0 and 3). The raw score (= summed score) of each scale is transferred to a standardized score. Higher scores correspond with higher amounts of symptoms.

Anxiety was assessed using the German Screening Test for Child Anxiety Related Emotional Disorders (SCARED; 64). The questionnaire's reliability measure obtained from the printed test manual for each informant is: Cronbach's alpha for mothers = 0.89, and for fathers = 0.93. The questionnaire is designed to assess children's anxiety. It is composed of 41 items: 13 items about panic/somatic symptoms; nine items about generalized anxiety; eight items about separation anxiety; seven items about social phobia; and four items about school phobia. The reliability measures obtained from the printed test manual are: Cronbach's alpha = 0.81, 0.81, 0.71, 0.75 and 0.66, respectively for the above-mentioned item groups. Items were scored on a four-point Likert scale (scores ranged between 0 and 3). The raw score (= summed score) of each scale is transferred to a standardized score. Higher scores correspond with higher amounts of symptoms.

Familial and environmental factors were assessed using a parental questionnaire. The questionnaire is designed to assess the parents' familial and childhood background. Parents were presented with items about their: familial, own and children's developmental problems and psychopathologies; experience with learning interventions; general familial history; level of obtained education; occupation; ethnicity; and lingual proficiencies. This variable was used as SES in the data analysis.

Analyses

Data preparation

Data were prepared and analyzed using REDCap [65] and R software [66]. Data preparation included the transformation of raw scores to z-scores separated by grade. Standardization was based on grade-specific norms for academic and intelligence tests based on the current representative sample, and based on age and gender-specific norms provided by the test manual for the psychopathological questionnaires. For all variables, higher scores indicate higher levels of skills, symptoms or involvement. For psychopathologies, combined scores were calculated for internal and external disorders based on the mean of the standardized scores for anxiety and depression, and for ADHD and conduct disorder, respectively.

Planned data analyses

Data Analyses were performed in the R software[66] using the Lavaan package [67]. Maximum Likelihood was used as the estimator for all computed models. Moreover, for all models, criteria suggested by Hu and Bentler[68] were followed when evaluating model fit: χ^2 not statistically significant ($p > .050$); comparative fit index (CFI) > 0.950; root mean square error of approximation (RMSEA) < 0.060; and standardized root mean square residual (SRMSR) < 0.080.

To answer research question [1] (Is there is a direct association between LD/learning skills and bullying, or does the association depend on other co-occurring disorders?), correlation analyses and path analyses were performed. To this aim, the first step was calculating correlations between the investigated variables. The second step was investigating all single paths by analyzing the following direct associations: is bully-victim involvement predicted by reading, spelling and math skills; is bully-victim involvement predicted by internal and external disorders; and are internal and external disorders predicted by reading, spelling and math skills. The third step was investigating two path models: the first included a direct path between LD and bullying; whereas the second did not (see Fig. 1). The two models were compared to test whether model fit is better with or without the direct path between LD and bullying.

To answer research question [2] (Do the associations differ when comparing children with and without LD?), a multigroup path analysis was performed. To this aim, a free model and a constrained model, with intercepts and path coefficients fixed to be identical for the two groups were compared. Then, as the models differed, the constraining of each path separately was explored. In order to clearly differentiate between children with and without LD, children scoring between −1.5 SD and −1 SD (assessments detailed above under "Children's assessments") were excluded from the analyses. Resultingly, the control group consisted of 2,180 of the children, and the LD group consisted of 373 children.

To answer research question [3] (Do these associations differ when examining either being both a bully and a victim compared to only being a victim or a bully), another path analysis was performed. To this aim, the variables described above were modeled with either only victimization or only bullying perpetration as the outcome variable. These models were compared to the model with combined bullying roles (i.e., bully-victim involvement) as the outcome variable to test whether models differ in either of the bullying roles.

To answer research question [4] (do the associations differ when examining different genders?), a multigroup analysis was performed (see multigroup path analysis description for research question 2). This analysis was performed to test whether there are gender differences in overall bullying involvement; in the overall model; and in any of the separate paths.

Finally, in order to assess whether the associations differ when taking IQ and SES into account, the variables described above were modeled with the addition of IQ and SES to the endogenous variables (internal and external disorders). This model was compared to the model without IQ and SES.

Results

Group comparisons between children with and without LD across the study variables (Table 1) revealed that compared to children without LD, children with LD had worse reading, spelling and math skills and had higher levels of internalizing and externalizing symptoms. With respect to bully-victim involvement, there was a small significant group difference (when tested one sided based on previous research), suggesting that the LD group was more involved in bullying compared to children without LD. However, the effect size was relatively small.

Firstly, to answer research question [1] (Is there is a direct association between LD/learning skills and bullying, or does the association depend on other co-occurring disorders?), correlation analyses between the investigated variables were performed. Nearly all correlations were significant on a 0.01 level (Table 2), with

Table 1 Mean differences of groups across study variables

Total N = 2553	No LD	SD	LD	SD	*p* - value	*Effect size (Cohen's d)*
N	2180		373			
Reading	0.45	0.76	-1.04	1.03	< 0.001	1.85
Spelling	0.44	0.76	− 0.98	1.05	< 001	1.76
Math	0.37	0.72	− 0.78	1.05	< 001	1.47
Internalizing	− 0.13	0.94	0.29	1.01	< 001	− 0.44
Externalizing	− 0.18	0.95	0.41	1.01	< 001	− 0.61
Bully-victim inv.	− 0.04	0.83	0.04	0.87	0.086	− 0.10

Note. All variables indicate z-scores separated by grade. *SD* is used to represent standard deviation

Table 2 Means, standard deviations, and correlations with confidence intervals

N = 2,925	*M*	*SD*	1	2	3	4	5
1. Reading	0.17	0.98					
2. Spelling	0.16	0.96	0.45**				
			[0.42, 0.48]				
3. Math	0.11	0.90	0.20**	0.32**			
			[0.16, 0.23]	[0.29, 0.35]			
4. Internal disorders	-0.05	0.97	− 0.14**	− 0.14**	− 0.16**		
			[-0.18, − 0.10]	[-0.17, − 0.10]	[-0.19, − 0.12]		
5. External disorders	-0.07	0.98	− 0.17**	− 0.23**	− 0.18**	0.56**	
			[-0.20, − 0.13]	[-0.27, − 0.20]	[-0.22, − 0.15]	[0.53, 0.58]	
6. Bully-victim inv.	-0.02	0.83	− 0.03	− 0.07**	− 0.06**	0.19**	0.25**
			[-0.07, 0.00]	[-0.11, − 0.03]	[-0.10, − 0.03]	[0.15, 0.22]	[0.22, 0.29]

Note. M and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .050$. ** indicates $p < .010$

the exception of the non-significant correlation between reading and bully-victim involvement. The correlations between bully-victim involvement, and learning skills (i.e., spelling and math skills) were all negative, indicating that poorer learning skills are associated with higher bully-victim involvement. The correlations between bully-victim involvement and both internal and external disorders were all positive and significant, indicating that more internalizing and externalizing symptoms are associated with higher bully-victim involvement. Notably, correlations seem to be higher for bully-victim involvement with externalizing disorders compared to with internalizing disorders. The correlations between all learning skills and internal and external disorders were negative and significant, indicating that poorer learning skills are associated with more internalizing and externalizing symptoms. Internalizing and externalizing disorders correlated similarly with learning skills.

Thereafter, three initial models were performed to test the direct associations between: bully-victim involvement and reading, spelling and math skills ($b = 0.002$, $t = 1.30$, $p = .896$; $b = -0.049$, $t = -2.658$, $p = .008$; $b = -0.044$, $t = -2.412$, $p = .016$, respectively); bully-victim involvement and internal and external disorders ($b = 0.056$, $t = 3.007$, $p = .003$; $b = 0.183$., $t = 9.983$ $p < .001$, respectively); and internal and external disorders and reading, spelling and math skills ($b = -0.089$, $t = -4.391$ $p < .001$; $b = -0.058$, $t = -2.740$, $p = .006$; $b = -0.133$, $t = -6.427$, $p < .001$, respectively for internal disorders; $b = -0.073$, $t = -3.327$ $p < .001$; $b = -0.166$, $t = -7.849$, $p < .001$; $b = -0.127$, $t = -6.195$, $p < .001$, respectively for external disorders). All three models were statistically significant (all p values < 0.001). This provided merit to continue with two more complex path models.

Specifically, reading, spelling and math skills were modeled as the exogenous variables. Internal and external disorders were modeled as the endogenous variables, and bully-victim involvement was modeled as the outcome variable. A model without the mediating path of internal and external disorders (i.e., the endogenous variables) showed that math and spelling skills were significant predictors of bully-victim involvement ($b = -0.040$, $t = -2.412$, $p = .016$; $b = -0.049$, $t = -2.658$, $p = .008$, respectively), while reading was not ($b = 0.002$, $t = 0.130$, $p = .896$). When adding the mediation to the model, none of the direct effects were significant, but internal and external disorders were significant predictors of bully-victim involvement ($b = 0.056$, $t = 3.006$, $p = .003$; $b = 0.180$, $t = 9.646$, $p < .001$, respectively). Moreover, for this model including the direct path, the following indices were obtained: $\chi^2(0, N = 2925) < 0.001$, $p < .001$; CFI = 1.00; RMSEA < 0.000; SRMSR < 0.000, which do not indicate a good fit to the data [68]. Next, as the direct paths between learning skills and bully-victim involvement were not statistically significant, a simpler model without the direct paths was analyzed. For this model, the following indices

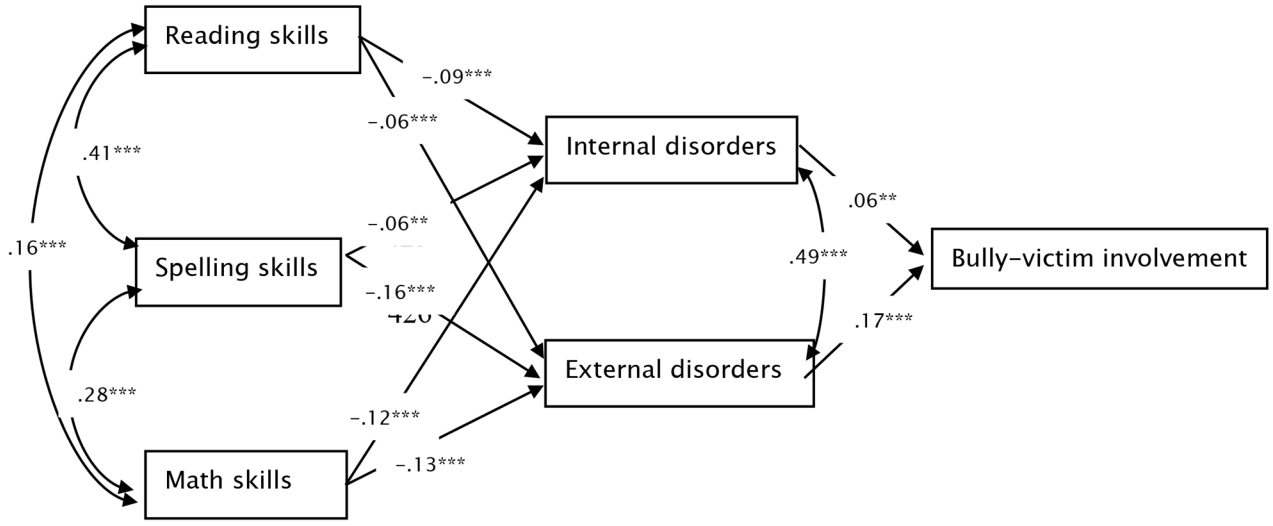

Fig. 1 The final path model. *Note*: The reported values are standardized path coefficients. Significance values: $p < .001$ '***', $p < .01$ '**', $p < .05$ '*'

Table 3 Correlations for the LD group and the control group with confidence intervals

LD	1	2	3	4	5
1. Reading					
2. Spelling	0.15**				
	[0.05, 0.25]				
3. Math	−0.34**	−0.11*			
	[-0.43, −0.25]	[-0.21, −0.01]			
4. Internal disorders	−0.04	−0.12*	−0.12*		
	[-0.14, 0.06]	[-0.21, −0.01]	[-0.22, −0.02]		
5. External disorders	0.01	−0.23**	−0.13*	0.60**	
	[-0.09, 0.11]	[-0.33, −0.13]	[-0.22, −0.02]	[0.54, 0.67]	
6. Bully-victim inv.	0.03	−0.09	−0.08	0.12*	0.23**
	[-0.07, 0.13]	[-0.19, 0.02]	[-0.18, 0.02]	[0.02, 0.22]	[0.13, 0.33]
Control					
1. Reading					
2. Spelling	0.29**				
	[0.26, 0.33]				
3. Math	0.08**	0.21**			
	[0.04, 0.13]	[0.17, 0.25]			
4. Internal disorders	−0.07**	−0.06**	−0.09**		
	[-0.11, −0.03]	[-0.10, −0.02]	[-0.13, −0.05]		
5. External disorders	−0.09**	−0.13**	−0.11**	0.52**	
	[-0.13, −0.05]	[-0.17, −0.09]	[-0.15, −0.07]	[0.49, 0.55]	
6. Bully-victim	−0.03	−0.06**	−0.05*	0.18**	0.25**
	[-0.07, 0.01]	[-0.10, −0.01]	[-0.09, −0.01]	[0.14, 0.22]	[0.21, 0.29]

Note. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .050$. ** indicates $p < .010$

were obtained: $\chi^2(3, N=2925)=2.34$, $p=.500$; CFI > 0.990; RMSEA < 0.001; SRMSR = 0.005, which indicate a good fit to the data [68]. Even though a comparison between the models revealed that they do not differ significantly ($p > .05$), the second model was chosen as the final path model as it was simpler and fit the data better (Fig. 1).

Portions of model variance were explained by: internal disorders, $R^2=0.040$ (4%); external disorders, $R^2=0.071$ (7.1%); and bully-victim involvement, $R^2=0.066$ (6.6%). Furthermore, the indirect effects of reading, spelling and math on the outcome variable (bully-victim involvement), through the endogenous variables (internal and external disorders) were all statistically significant (all b values between −0.003 and −0.030, and all p values between 0.001 and 0.043). These indirect effects were significant through internalizing disorders: reading ($ab=-0.005$, 95% CI [-0.010, −0.002]), spelling ($ab=-0.003$, 95% CI [-0.010, −0.001]), math ($ab=-0.007$, 95% CI [-0.010, −0.003]) and through externalizing disorders: reading=$ab=-0.010$, 95% CI [-0.020, −0.010], spelling=$ab=-0.030$, 95% CI [-0.040, −0.020] and math=$ab=-0.020$, 95% CI [-0.030, −0.020]).

Next, to answer research question [2] (Do the associations differ when comparing children with and without LD?), a multigroup path model with the two groups (LD and a control group) was performed (see Table 3 for the correlations for each group). The explained variance values in the LD group were for the most part slightly higher than those observed in the control group: internal disorders, $R^2=0.036$ (3.6%) vs. $R^2=0.013$ (1.3%), external disorders, $R^2=0.077$ (7.7%) vs. $R^2=0.027$ (2.7%), and bully-victim involvement, $R^2=0.054$ (5.4%) vs. $R^2=0.068$ (6.8%). The multigroup path model was respecified in two group variations: a free model and a constrained model,

with intercepts and path coefficients fixed to be identical for each of the groups. For these models, the following indices were obtained: $\chi^2[6]=3.398$, $p=.758$; CFI > 0.990; RMSEA < 0.001; SRMSR = 0.007; $\chi^2[20]=765.316$, $p<.001$; CFI = 0.492; RMSEA = 0.171; SRMSR = 0.153, respectively. These indices indicate that the free model fits the data better than the constrained model [68]. A comparison between these models revealed that the difference between the free and the constrained model was statistically significant ($p<.001$), indicating that the models for the two groups are not identical. In order to identify if specific paths differ between groups, we released the constraints of each path one-by-one. This analysis revealed that the groups differed only in the path between spelling and externalizing symptoms. However, for both groups, the path was highly significant ($p<.001$) albeit slightly more pronounced in the LD group ($b=-0.237$, $t=$ -4.925, $p<.001$; $b=-0.127$, $t=$ -4.479, $p<.001$, respectively for the LD group and the control group).

After that, to answer research question [3] (Do these associations differ when examining either being both a bully and a victim compared to only being a victim or a bully), the outcome variable for the final model described above, was respecified. Specifications were to either have only victimization or only bullying perpetration as the outcome variable. Again, the pattern observed when the outcome variable was only victimization or only bullying perpetration was comparable to the one observed with the combined bully-victim involvement variable: internal disorders, $R^2=0.040$ (4%) vs. $R^2=0.040$ (4%) vs. $R^2=0.040$ (4%); external disorders, $R^2=0.058$ (5.8%) vs. $R^2=0.071$ (7.1%) vs. $R^2=0.071$ (7.1%); and victim/bully/bully-victim involvement, $R^2=0.058$ (5.8%) vs. $R^2=0.039$ (3.9%) vs. $R^2=0.066$ (6.6%).

Afterwards, to answer research question [4] (do the associations differ when examining different genders?), an independent t-test was used to examine potential gender differences in bully-victim involvement. There was a significant difference in bully-victim involvement between boys ($M=0.049$, $SD=0.850$) and girls ($M=-0.099$, $SD=0.810$), wherein boys demonstrated significantly higher bully-victim involvement, $t(2921)=4.82$, $p<.001$. Thereafter, a multigroup path model was respecified in two gender variations: a free model and a constrained model, with intercepts and path coefficients fixed to be identical for each of the genders. For these models, the following indices were obtained: $\chi^2[6]=8.322$, $p=.215$; CFI = 0.999; RMSEA = 0.016; SRMSR = 0.010; $\chi^2[20]=133.801$, $p<.001$; CFI = 0.955; RMSEA = 0.062; SRMSR = 0.040, respectively. These indices indicate that the free model fits the data better than the constrained model [68]. A comparison between these models revealed that the difference between the free and the constrained model was statistically significant ($p<.001$), indicating that the models are not identical for males and females. Next, a series of models was used to explore each path separately by releasing the constraints of each path one-by-one. This analysis revealed that the difference between males and females was not statistically significant in any of the single paths.

Finally, to assess whether associations differ when taking IQ and SES into account, the endogenous variables for the final model described above, were respecified. Due to missing items, the resulting sample size decreased to $N=2454$. Interestingly, only IQ accounted for a significant amount of variance of the outcome variable. For the most part, in comparison with the final model described above, there was a decrease in the portions of model variance explained by, respectively: internal disorders, $R^2=0.028$ (2.8%) vs. $R^2=0.040$ (4%); external disorders, $R^2=0.060$ (6%) vs. $R^2=0.071$ (7.1%); and bully-victim involvement, $R^2=0.072$ (7.2%) vs. $R^2=0.066$ (6.6%).

Discussion

Both LD and bullying are major sources of public concern [6, 20]. Previous research on the interplay between the two yielded inconsistent patterns. Specifically, it was not clear whether LD are a direct childhood bullying risk factor, or whether the association depends on co-occurring disorders. The current study is the first to demonstrate that LD are not a direct childhood bullying risk factor. Rather, LD are only a risk factor when there are co-occurring psychiatric symptoms. Namely, once children have LD, they are more likely to also suffer from psychiatric comorbidity, and consequently their risk of being involved in bullying as both bullies and victims increases (Fig. 1). These findings suggest that for such children, early bullying prevention could be useful to hinder consequential negative effects.

The current study also sought to investigate sample and bullying role differences, as well as other potentially relevant factors, namely gender, IQ, and SES.

In terms of sample differences, comparing the models between children with and without LD revealed an overall difference between the two groups. However, when analyzing each path separately, significant differences were only found in the path between spelling and externalizing disorders, wherein a negative effect size was more pronounced in the LD group, even though the path was highly significant for both groups.

In terms of different bullying roles, we did not find differences between models. One possible reason is that children with LD involved in bullying are prone to be both victims and bullies. This is in line with previous research arguing for bully-victim duality (e.g., 51). This duality could be explained as follows: children with LD often find it harder to socialize with their peers (e.g., 18); as a result, they have less protection from their social

group, and are at greater risk of being rejected and bullied [17]; some victims react aggressively to bullying, and thus, in turn, they become bullies as well [51]; in parallel, children with LD are likely to suffer from co-occurring disorders (e.g., ADHD; 14); such co-occurrences, especially co-occurrences with externalizing disorders, increase the likelihood of victims reacting aggressively to bullying, and thus, the bully-victim duality is reinforced [52].

In terms of gender, gender differences were not found in any of the specific paths of the final model (Fig. 1). Nonetheless, an overall difference did emerge, wherein boys were more involved in bullying compared to girls. This gender difference is compatible with some past research investigating the role of LD as childhood bullying risk factors (e.g., 40, 43, 46). In terms of IQ and SES, it is likely that little to no differences in the models were found when they were controlled, because involvement in bullying is influenced by many factors. Moreover, although IQ accounted for a significant amount of variance in the outcome variable, including IQ did not improve model fit, likely due to an overlap with learning skills. This is in contrast to previous research that has found that IQ and SES are prominent bullying risk factors (e.g., 34). It is possible that this discrepancy is due to IQ and SES being indeed risk factors, but lessening in influence when examined alongside other factors. Alternatively, participants could have belonged to the higher end of the SES distribution (i.e., the sample has less variation). It is possible that the predictive patterns are different in the higher end of the distribution compared to the full range of SES. In terms of future research, it would be useful to ensure the sample encompasses the full range of SES.

Several limitations merit a brief discussion. Firstly, the total explained variance of bullying in the current study was only 6.6%. Similarly, for Klomek et al. [43], the total explained variance of victimization was 7%. They rationalized this by stating that there are numerous other potentially influential factors that could be accounted for in future research. Nevertheless, their study was the first to examine the association between LD, ADHD and bullying, and contributed to the development of the research field. The current study adds to the existing literature by examining the association between different LD (i.e., reading, spelling and math disorders), several comorbid disorders and different bullying roles. Although the current study could not control for all potentially relevant environmental factors (e.g., social support), it did control for gender, IQ and SES, factors that did not increase the explained variance. Secondly, the current study had a cross-sectional design, and participants' mean age was 9.72 years, whereas bullying is most prominent at ages 11–13 [69]. In terms of future research, it would be useful to adapt the model to a longitudinal design to better understand the developmental trajectories, and to also sample older children. Thirdly, bullying involvement was measured using self-report only, and did not account for the social context in which bullying naturally occurs. Using such a measurement could have led to an underrepresentation, as discussed by Fogler et al. [70], especially since bullying is often considered a socially undesirable behavior. In terms of future research, different measurements (e.g., peer popularity ratings) should be used in order to incorporate the social context and encourage a more realistic representation. Despite these limitations, the current study enhances the understanding of the link between comorbid LD and bullying, and will hopefully stimulate further investigation of this important area.

The study has the following practical implication: First, it confirms that bullying is another hurdle children with comorbid LD might have to face. Second, it provides merit for school professionals to pay more attention to children with comorbid LD, and enforce pre-defined policies on how to respond to acts of bullying towards and among these children. Third, it also provides merit to focus on children with comorbid LD as a specific risk group in bullying intervention programs. As the association found between LD and bullying is compatible with the assumption of bullying role duality (i.e., being both a victim and bully), such interventions should encompass coping strategies for both roles. In addition to program inclusion, personal support could be offered to children with comorbid LD that have been recognized by parents or school professionals as prone to being involved in bullying. Finally, the association found in the current study could serve as theoretical grounding for future research investigating the association between comorbid LD and cyberbullying. Amid the Covid-19 pandemic, as more traditional schooling was replaced with online learning, alongside traditional bullying, cyberbullying has emerged as an issue of utmost relevance [71]. Moreover, the daily amount of time youths spend on a computer increases the risk of cyberbullying involvement [72]. Using interactive computer software, such as Cyberball [73], cyberbullying could be experimentally simulated (e.g., 74 used Cyberball to simulate cyberbullying in participants with depression and borederline personality disorder via a virtual ball tossing game with other participants). Future research could compare Cyberball responses of children with comorbid LD with those of typically developing controls. In the domain of LD, a few studies have already used self-report and parental questionnaires to show that comorbid LD increases the likelihood of cyberbullying involvement (e.g., 75, 76). Future research could contribute to this important research realm by comparing traditional bullying to cyberbullying among children

with and without comorbid LD, incorporating interactive simulations, and taking into account further factors such as social support and the daily amount of time children spend online.

Conclusion

The current study demonstrated that learning disorders are an indirect childhood bullying risk factor, as their impact depends on psychiatric comorbidity with internalizing (i.e., anxiety and depression) and externalizing disorders (i.e., ADHD and conduct disorder). The importance of this finding is the identification of children with such co-occurrences as a risk group, to which anti bullying interventions could be tailored and enforced. Furthermore, this finding adds to previous inconsistent findings on the association between LD and bullying by showing that there is an indirect rather than a direct relationship. Moreover, the study provides grounds for future studies with this risk group (i.e., LD with psychiatric comorbidity), encompassing both traditional bullying and cyberbullying, with the latter becoming increasingly widespread as many children increased their online interactions amid the Covid-19 pandemic.

Abbreviations

ADHD	Attention-deficit/hyperactivity disorder
BMI	Body mass index
CODY-M 2–4	Cody math test
CFI	comparative fit index
CFT 20-R	Culture Fair Intelligence Tests
DISYPS-II	Psychopathological profile questionnaire
DSM-5	The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition
LD	Learning disorders
LGBTQ+	Lesbian, gay, bisexual, transgender and related communities
OBQ	Olweus bully/victim questionnaire
RMSEA	Root mean square error of approximation
SCARED	Screening Test for Child Anxiety Related Emotional Disorders
SD	Standart deviations
SES	Socioeconomic status
SRMSR	Standardized root mean square residual
WLLP-R	Würzburger silent reading test – revised
WRT 3+	Weingartener spelling test for basic vocabulary for 3rd graders
WRT 4+	Weingartener spelling test for basic vocabulary for 4th graders

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Authors' contributions

LW contributed to the conception of the study design, analyzed and interpreted the data, and was a major contributor in writing the manuscript. SH contributed to the conception of the study design and data analyses. GSK contributed to the data interpretation and draft revisions. KM contributed to the data collection and draft revisions, and was a major contributor in data analyses. All authors read and approved the submitted manuscript.

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Data availability

The datasets used and/or analyzed during the current study are not publicly available due to further planned research, but are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained by the Ethics committees of the University Hospital of the Ludwig-Maximilians-University Munich and of the DIPF | Leibniz Institute for Research and Information in Education. Written informed consent to participate was obtained from the children's legal guardians.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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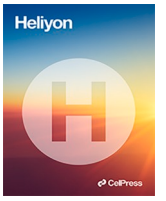

Research article

Evaluating a German learning disorders platform using the RE-AIM framework

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ABSTRACT

In recent years, online platforms have made educational, medical, and other professional content easily accessible, but research evaluating such platforms is still scarce. The purpose of the current study is to evaluate LONDI, a German learning disorders platform. The platform offers scientifically based information for different user groups, and an algorithm-based help system that professionals can use to facilitate diagnosing and planning interventions. The evaluation is focused on the user group of learning therapists using the platform and its help system. It is theoretically grounded on the RE-AIM framework and assesses four of its dimensions: Reach, Adoption, Implementation and Maintenance. Results from an online questionnaire ($N = 496$) showed that the platform reaches a large proportion of learning therapists. Another online questionnaire ($N = 150$) revealed that most users say they would adopt the help system, and this is predicted by its pragmatic qualities. Data from the Matomo web analytics software ($N = 8{,}459$ online visits) displayed diverse patterns in the platform's implementation. Future research is needed to further examine their meaning in the context of health-related education. Web analytics also revealed that usage patterns are not maintained. Rather, there is an increase in the number of users and in smartphone usage over time, coinciding with a decrease in the average time spent on the platform. Consequently, future efforts will be dedicated to optimizing smartphone compatibility. This study is the first to utilize the RE-AIM framework with web analytics, paving the way for further theory-grounded platform evaluations.

1. Introduction

In recent years, the rise in digitalization has made it both possible and advisable for printed content to become easily accessible online This possibility is also being leveraged for health-related educational content, made widely available through online platforms [1]. In turn, online platforms necessitate research evaluating if they are indeed effective (e.g., [2,3]).

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1.1. LONDI: a German learning disorders platform

The present study aims to evaluate LONDI, a German learning disorders platform (www.londi.de). Learning disorders are generally defined as persistently lagging academic skills and performance [4]. Worldwide, 5–15 % of all children fulfill the diagnostic criteria for a learning disorder (American Psychiatric Association, 2013; Horowitz et al., 2017). Specifically, affected children suffer from deficits in reading, spelling, and or arithmetic. Adding to this difficulty, they are also likely to suffer from other comorbid disorders (e.g., ADHD; [5]). This, in turn, contributes to their susceptibility to social difficulties (e.g., bullying; [6]). Importantly, learning disorders are not explained by intellectual disabilities, poor auditory or visual abilities, limited motivation, or limited possibilities to acquire education. Moreover, they are accounted by both genetic and environmental factors [7]. When children with learning disorders try and fail to master basic academic skills and do not receive appropriate help, they are likely to get frustrated and either act out or give up [8]. Therefore, it is crucial to provide them with appropriate support.

To support children with learning disorders, the LONDI platform was tailored to the needs of five different user groups interacting with affected children: parents, learning therapists, teachers, school psychologists and social workers. LONDI provides both user specific information and support. In terms of information, LONDI provides scientifically based content about specific learning difficulties. The information is different for each user group to best accommodate for their specific needs (e.g., only the section for social workers includes a breakdown of the law on assistance integration). In terms of support, LONDI includes parental coaching and an algorithm-based help system for professionals (e.g., learning therapists).

The help system serves as a tool to identify the appropriate diagnostic or intervention recommendations for each child, according to their individual learning profile. To this aim, prior to the current study, possible diagnostic and intervention tools were assessed based on scientific quality criteria. The quality criteria included: theoretical basis, objectivity, reliability, validity and unambiguity. Accordingly, recommendations were classified using a star system (e.g., one star means criteria were not met, and three means all criteria were met). Moreover, prior to the current study, each recommendation was classified according to four competence levels. The competence levels were founded on widely used developmental models for literacy [9,10] and arithmetic skills [11,12]. These developmental models encompass age-appropriate skill acquisition and competencies. The four competence levels used in the help system indicate what each recommendation covers for every learning skill. The first competence level refers to basic skills, the second to initial skills, the third to standard skills, and the fourth to applied and flexible skills. The priorly assessed and classified diagnostic and intervention tools serve as a database for the help system. When a professional uses the help system, an algorithm uses this database to match the data they insert with the most suitable recommendations. Along with the name and information for each recommendation, the help system also displays which competence levels the recommendation covers, the sample size and year in which its norms were calculated and its scientific quality rating. For experienced learning therapists, this process takes approximately 5 min per recommendation. A detailed breakdown of the help system steps is appended to this manuscript.

1.2. Online evaluation research

To date, online evaluation research varies considerably. Whereas some research focused on data from various user analytics matrices to evaluate online behavior (e.g., [13–17]), other research combined user analytics data with various self-report measures (e.g., [18–25]). Notably, a recent evaluation by Merkt et al. [26] combined user log files, behavioral data from a laboratory study, and objective content characteristics. Likewise, we sought to combine different methods for an encompassing evaluation, which we grounded on a theoretical framework. Namely, the RE-AIM framework.

1.3. RE-AIM framework

RE-AIM is a theoretical framework often used for evaluating public health interventions [27,28]. As suggested by Glasgow et al. [28], it is optimal to use mixed-methods while using the RE-AIM framework. RE-AIM assesses five dimensions: Reach, Effectiveness, Adoption, Implementation and Maintenance. *Reach* addresses the proportion of the target population an intervention reaches (e.g., [29,30]); *Effectiveness* addresses an interventions' success rate in terms of its impact on individual outcomes (e.g., [31]); *Adoption* addresses the proportion of users that adopt an intervention (e.g., [32]); *Implementation* addresses the manner in which an intervention is applied in real-life settings (e.g., [33]); and *Maintenance* addresses the manner in which an intervention is used over time (e.g., [34]).

1.4. Web analytics

A suitable method for evaluating an online platform is using web analytics (e.g., [35]). While the most prominent web analytics software is Google Analytics, Matomo is a software that provides an optimal alternative, compatible with European data ownership and privacy law [36,37]. Matomo's features provide insight on the behavior of online users via anonymous visitor profiles and various matrices including users' location and software. Moreover, Matomo includes features to evaluate usage via pre-defined objectives. The pre-defining of objectives can include specified goals (e.g., pages you want users to visit), and funnels (i.e., the steps users go through on their way to the goals).

Although Matomo and other web analytics software are still predominantly used for commercial and marketing purposes [14], in recent years, there has been a shift towards utilizing web analytics for scientific research. Several studies have used Matomo to evaluate online health related educational content (e.g., [17,19,20,22,23,35]). At present, however, it seems that none have used the RE-AIM framework [27] as a theoretical backbone. Arguably, given the plethora of evaluation studies grounded on RE-AIM in various

settings for over two decades [28], and its recent usage in several notable digital platform evaluations (e.g., [38–41]) it can be deemed a suitable framework for the current study. Thus, generating more research utilizing web analytics for theory grounded scientific evaluation research.

1.5. The current study: hypotheses

The current study's goal is to evaluate LONDI using the RE-AIM framework. It was pre-registered as part of a larger evaluation project. This project contains two more pre-registered studies that differ from the current study in their focus, sample, theoretical background and methods [42,43]. Specifically, the other studies use a sample of recruited participants, as well as a mixed-method approach containing both quantitative and qualitative measures. In contrast, the current study was framed within a real-world setting of anonymous online users, using LONDI of their own volition (i.e., not as part of an experiment). Due to this real-world setting, the current study uses a solely quantitative approach. The current study's hypotheses were grounded on four of the RE-AIM dimensions: Reach, Adoption, Implementation and Maintenance. The study does not include the Effectiveness dimension since there was no feasible measurement for intervention success based on Matomo data (e.g., improvement in therapeutic outcomes). This is in line with past research that only focused on the RE-AIM dimensions within their scope of feasibility (e.g., [29,33]). Moreover, Glasgow et al. [28] recommended to only focus on the RE-AIM dimensions compatible with a study's hypotheses and within its scope. Comparable with other web evaluations, we focused on a homogeneous user group experienced with developmental learning disorders, and on specific pages or sections (e.g., [17]). Namely, we focused on learning therapists, their designated pages, and the evaluation of the help system.

In line with the official RE-AIM website [44], which defines Reach as the absolute number, proportion, or representativeness of users, we formulated the first hypothesis. Hypothesis 1: The relative percentage of learning therapists using the platform will be higher than their percentage in the general German population. Moreover, in line with the RE-AIM scoring instrument [45] and the official RE-AIM website [44], which define Adoption as the number of users willing to use a program, and encourage an evaluation of the qualities of a program that influence Adoption, we formulated the second hypotheses. Hypothesis 2a: Users will state that they intend to keep using the help system. Hypothesis 2b: Users will rate the system as above average in terms of pragmatic and hedonic qualities. Hypothesis 2c: The pragmatic and hedonic ratings will predict the intention to use the help system. Additionally, considering the official RE-AIM website [44], which defined Implementation as the percentage of achieved process objectives, we formulated the third hypothesis. Hypothesis 3: The platform will be fully implemented by learning therapists reaching it via all possible online paths (i.e., links). Lastly, in line with the official RE-AIM website [44], which defined Maintenance as the assessment of how and why a program did or did not prosper over long-term usage, we formulated the fourth hypothesis. Hypothesis 4: Therapist content usage will change over time, as indicated by comparing platform usage in different time-segments (i.e., 01.01.23–31.03.23 vs. 01.04.23–30.06.23).

2. Methodology

2.1. Sample

The sample consisted of $N = 8{,}459$ LONDI visits that took place in the six months between 01.01.23 and 30.06.23. Beforehand, approval was obtained from the ethics committees in all collaborating institutions. Moreover, before answering any of the

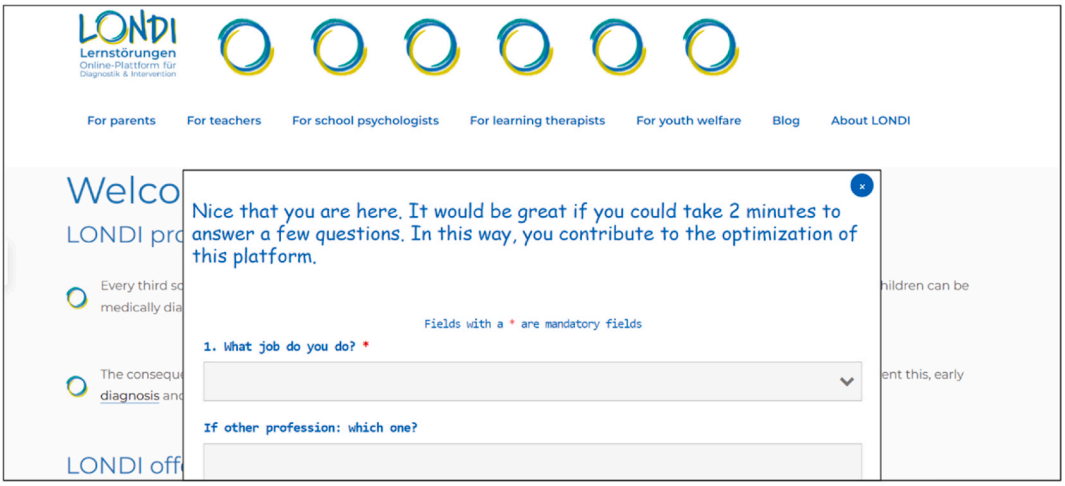

Fig. 1. Screenshot of the demographic pop-up questionnaire appearing in the front page.
Note. The demographic pop-up questionnaire and the front page that appear in this screenshot were translated from German to English for the benefit of non-German speaking readers.

questionnaires, users were asked to give informed consent, in accordance with the Declaration of Helsinki. Most visits originated from search engines ($n = 5,707$) and direct entries ($n = 2,296$). Others originated from links in other websites ($n = 393$) and social media posts ($n = 63$). Moreover, most visits were from Germany ($n = 6,684$) and among these mostly from the city Frankfurt am Main ($n = 3,912$). Notably, the relatively large sample from Frankfurt am Main can be explained by the fact that one of the partner universities working on LONDI and advertising the platform is located there. Among others, visits were also from Offenburg ($n = 355$), Munich ($n = 257$) and Düsseldorf ($n = 132$). Furthermore, most visits were done via smartphones ($n = 5,129$), followed by desktops ($n = 2,991$). The average visit duration was 2 min and 15 s.

2.2. Measures

To test the hypotheses for each of the RE-AIM dimensions, the following operationalizations and assessments were planned.

2.2.1. Reach

Operationalization for hypothesis 1 (Reach: percentage of learning therapists using the platform): Data on users' profession was gained via an optional demographic pop-up questionnaire, filled out voluntarily by a sub-sample of the platform users. Completing the questionnaire takes 2 min at most. Moreover, it appears to all first-time users on the front page (see Fig. 1). Possible answers are the German equivalents of: a. teacher, b. school psychologist, c. learning therapist, d. no profession/unemployed, e. other. This was used to determine what percentage of the users visiting the platform are learning therapists. Thus, the percentage of learning therapists among all other professions indicated in the pop-up was calculated. Then, it was compared to the percentage of learning therapists in the entire German population.

2.2.2. Adoption

Operationalization for hypothesis 2 (Adoption): Data was collected via the German equivalent of the item: "I plan to continue using LONDI" that appears in an optional pop-up questionnaire in the help system, and was taken from a validated questionnaire [46]. Possible answers are the German equivalents of: a. Do not agree at all, b. Do not agree, c. Strongly disagree, d. Neutral, e. Tend to agree, f. Agree, g. Fully agree. At present, there are no benchmarks for the used item in the context of health interventions and online platforms. We therefore used the mean user rating of the answers on a 7-point scale (1 = Do not agree at all to 7 = Fully agree) as cutoff to define adoption. Namely, if participants scored above the mean of 4, we consider it as an indication for intention to adopt the help system. In previous research, this item was often used in combination with other items to gain deeper understanding of underlying usage mechanisms (e.g., [47,48]). This was also done in the current study as described in the following passage.

To gain a deeper understanding of why users intend to keep using the help system or not, the same pop-up questionnaire contained the short version of the User Experience Questionnaire, assessing the pragmatic and hedonic qualities of the help system (UEQ-S; [49]). Completing the UEQ-S takes 2 min at most. The UEQ-S is widely used to measure how users subjectively experience a product (e.g., [50]), and includes benchmarks for interpretation (see Table 1). The UEQ-S includes eight items assessing the help system's hedonic and pragmatic qualities (i.e., four items for each), on a 7-point scale. Each item is represented by two opposite terms. Moreover, they are scaled from −3 (i.e., the most negative answer) to +3 (i.e., the most positive answer), with 0 representing a neutral answer. All German UEQ-S items used for the study, as well as the English version are appended to this manuscript. Below are examples of one pragmatic and one hedonic item, respectively:

I find the LONDI help system:
complicated o o o o o o o easy
boring o o o o o o o exciting.
For both examples, the utmost left circle is scaled as −3, and the utmost right circle as +3.

2.2.3. Implementation

Operationalization for hypothesis 3 (Implementation): Data on how the learning therapist user group implements the platform was collected using the Matomo analytics software. For this, we used the goals and funnels features, which must be pre-defined. The goals are defined as target pages one wants users to visit. The funnels are defined as different paths users can take to reach these goals. Once these are defined, data is collected revealing users' entry points and drop-offs during their journey across the platform toward the pre-defined goals. By defining goals and funnels, it is possible to determine where one loses visitors in converting one's goals. In londi.de, the three pages intended for learning therapists are.

1 For learning therapist page

Table 1
Mean User Experience Questionnaire (UEQ-S) ratings of the current study compared to Benchmarks retrieved from Hinderks et al. [51].

		Benchmarks				
Qualities	Mean rating	Excellent	Good	Above average	Below average	Bad
Pragmatic	1.23	>1.73	1.55–1.73	1.15–1.54	0.73–1.14	<0.73
Hedonic	1.29	>1.55	1.25–1.55	0.88–1.24	0.57–0.87	<0.57
Overall	1.26	>1.58	1.4–1.58	1.02–1.39	0.68–1.01	<0.68

2 Information for learning therapist page
3 Help system

For the sake of brevity, from this point forward, the front page is referred to as "Front," the for learning therapists page as "Index," the help system page as "Help System" and the information for learning therapists page as "Information." The aim of the Front page is to serve as an index page used to direct learning therapists to other pages. Thus, it does not contain a lot of content, with its primary goal to help users find what they are looking for (e.g., a link to detailed information on learning therapy). In contrary, the other two pages are goal pages, and contain detailed information (e.g., information on who finances learning therapy). For the present study, we have defined the goals as reaching the above-mentioned pages meant for learning therapists, and the funnels as the different paths learning therapists can take to reach these pages. To reach any of the above-mentioned pages, there are six possible sequences.

Subsequently, the six paths were defined as follows.

1. Front - > Index
2. Front - > Help System
3. Front - > Index - > Help System
4. Front - > Information
5. Front - > Index - > Information
6. Front - > Information - > Help System

During the data collection period, the number of users completing or not completing these paths was analyzed, also known as conversion and abandonment rates, respectively. Path abandonment in this context is comparable with bounce rates, a term often used in online marketing to refer to the percentage of online visits that end after just one pageview [14]. Acceptable bounce rates are highly dependent on the specific web page, its goals, and its contents. At present, there are no benchmarks for bounce rates in the context of online platforms related to learning disorders, but rather from the realm of online marketing. Such benchmarks for marketing campaigns [52] are as follows.

- 25 % or lower: Bad – there might be a technical issue underlying such low rates since most websites' bounce rate range is between 26 and 70 %.
- 26–40 %: Excellent.
- 41–55 %: Average.
- 56–70 %: Higher than normal but could make sense if the content fulfills the users' needs. and they do not feel the need to look at other pages afterwards.
- 70 % or higher: Bad – there might be a technical issue underlying such high rates such as slow loading time, a misleading title, or content that is not smartphone friendly.

2.2.4. Maintenance

Operationalization for hypothesis 4 (Maintenance): Data on platform usage in different time-segments (i.e., 01.01.23–31.03.23 vs. 01.04.23–30.06.23) was compared using the Matomo analytics software. Specifically, the number of users using LONDI in the first three months was compared with the last three to see whether the number has increased, remained as it was, or decreased. Furthermore, we compared: users' locations, time spent on the platform in general and on specific pages, number of actions, times of the day in which the platform was being used, and the devices and software used.

2.3. Analyses

Matomo indices were used to analyze online user behavior, within a six-months period (i.e., 01.01.23–30.06.23). Furthermore, a confirmatory factor analysis was run to assess whether the UEQ-S items indeed load on two factors (i.e., hedonic and pragmatic). Lastly, multiple linear regression (MLR) was used to find out whether the help system's hedonic and pragmatic qualities predict intention to use (i.e., the answer to the statement "I plan to continue using LONDI").

3. Results

3.1. Reach

To test hypothesis 1 (Reach): Data on users' profession was collected via an optional demographic pop-up questionnaire that appears to all first-time users on the front page. Notably, we only included learning therapists that used LONDI of their own volition. A total of $N = 496$ visitors answered the questionnaire. Among these, 17.53 % ($n = 87$) reported that they are learning therapists ($n = 85$ females). In terms of experience: 10 % ($n = 9$) were self-proclaimed novices; 23 % ($n = 20$) had 1–5 years of professional experience; 24 % ($n = 21$) had 6–10 years of professional experience; 29 % ($n = 25$) had 10–20 years of professional experience; and 14 % ($n = 12$) had more than 20 years of professional experience. The 18+ population in Germany in 2022, and the above 19+ population in Austria in 2023 were approximately 70 and 7 million, respectively [53,54]. Within the German population, the number of learning therapists is not publicly regulated. However, based on correspondence with the German Association for Dyslexia & Dyscalculia (BVL), it is

estimated that the combined number in Germany and Austria (there are no separate estimates for the countries) is 2,500 [55]. Given this estimate, their proportion in the adult German population is smaller than 0.0001 %. This supports hypothesis 1, that the relative percentage of learning therapists using the platform is higher than their percentage in the general German population.

3.2. Adoption

To test hypothesis 2 (Adoption): Data was collected via the item: "I plan to continue using LONDI" that appears together with the UEQ-S in an optional pop-up questionnaire in the help system. A total of $N = 150$ visitors answered the questionnaire. The item was rated on a 7-point scale (1 = Do not agree at all to 7 = Fully agree). The mean rating was 5.90. As there are no benchmarks for the single item evaluation, and since this mean is above 4, we consider it as an indication for intention to adopt the help system. This supports hypothesis 2a, stating that users intend to keep using the help system. To compare the results with the UEQ-S scores detailed below, we re-coded the answers from −3 (i.e., for the most negative answer) to +3 (i.e., for the most positive answer), with 0 representing a neutral answer, resulting in a mean rating of 1.90.

We then calculated the mean answers to the UEQ-S items assessing the pragmatic and hedonic qualities of the help system. Due to a programming error, the UEQ-S was rated on an 8-point scale instead of 7. To correct this, the scale was transformed. Namely, the two middle points were merged (as they represent the neutral options), and we calculated the other answers as intended from −3 (i.e., the most negative answer) to +3 (i.e., the most positive answer), with 0 representing the neutral answer. The mean scores and their interpretation according to the benchmarks are: 1.23 for the pragmatic qualities, which is above average, and 1.29 for the hedonic qualities, which is good. The overall score was 1.26, which is above average (see Table 1). This supports hypothesis 2b, stating that users will rate the system as above average in terms of pragmatic and hedonic qualities.

Moreover, a confirmatory factor analysis (CFA) was performed to assess whether the UEQ-S items indeed load on two factors (i.e., hedonic and pragmatic). Each factor was indicated by the hedonic and pragmatic variables based on Schrepp et al. [49]. The CFA was performed using the lavaan package in R (version 4.3.0). The CFA model fit was evaluated using the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), and Standardized Root Mean Square Residual (SRMR). The fit indices for the model were as follows: CFI = 0.91; TLI = 0.85; RMSEA = 0.14; SRMR = 0.06. Overall, the model shows a moderate to good fit [56].

Additionally, a multiple linear regression (MLR) was used to find out whether the help system's hedonic and pragmatic qualities predict intention to use via the answers to the statement "I plan to continue using LONDI." The model was statistically significant, $F(2,156) = 24.94$, $p < .001$, and explained 23 % of the variance. While the pragmatic qualities had a significant positive effect on the intention to use, $t(156) = 3.00$, $p = .003$, it was not statistically significant for the hedonic qualities $t(156) = 1.97$, $p = .051$. This only partially supports hypothesis 2c, stating that pragmatic but not hedonic ratings will predict the intention to use the help system.

3.3. Implementation

To test hypothesis 3 (Implementation): Data using the Matomo goals and funnels features was collected. We defined the goals as reaching the pages meant for learning therapists, and the funnels as the different paths learning therapists can take to reach them. Thereafter, path continuation (i.e., conversion) and abandonment rates were calculated and evaluated according to bounce rate marketing benchmarks ([52]; see Table 2). Notably, within the sample of $N = 8,459$ LONDI visits, $n = 3,108$ and $n = 1,326$ were visits to the help system and the learning therapists pages, respectively.

As seen in Table 2, three of the six paths had good abandonment rates, ranging between average and excellent according to marketing benchmarks. Specifically, abandonment rates for path 1 (i.e., Front - > Index); path 2 (i.e., Front - > Help System); and path 6 (i.e., Front - > Information - > Help System) were excellent, average, and average, respectively.

Notably, abandonment rates for path 4 (i.e., Front - > Information) were relatively low (i.e., 8.4 %) and considered bad. In the context of marketing, this might be interpreted as a technical problem. However, in the context of LONDI, low abandonment rates might indicate that the page served as the visitors' goal. This is in line with this page's purpose, which is to give users detailed information rather than refer them to other pages (i.e., the opposite of an index page). Thus, this might indicate that the purpose of many LONDI learning therapist users is to get detailed information via this page.

In contrast, abandonment rates for path 5 (i.e., Front - > Index - > Information) were relatively high (i.e., 74.5 %) and are also considered bad. Since each additional step adds an additional possibility to abandon the path, and this path includes three steps, by

Table 2
Data on path conversion and abandonment *rates*

Path	Conversion Rate	Abandonment Rate	Interpretation according to bounce rate benchmarks
1. Front - > Index	68.6 %	31.4 %	Excellent (26–40 %)
2. Front - > Help System	55.9 %	44.1 %	Average (41–55 %)
3. Front - > Index - > Help system	34.7 %	65.3 %	Higher than normal (56–70 %)
4. Front - > Information	91.6 %	8.4 %	Bad (25 % or lower)
5. Front - > Index - > Information	25.5 %	74.5 %	Bad (70 % or higher)
6. Front - > Information - > Help System	48.5 %	51.5 %	Average (41–55 %)

Note. Bounce rates benchmarks retrieved from Willson ([52]). Benchmark range is indicated within parentheses. Front = front page; Index = for learning therapists page; Help System = help system page; Information = information for learning therapist page.

default abandonment rates would be higher than the path with only the first two steps (i.e., path 1). Moreover, it could be that experienced learning therapists did not enter the information page because they are already familiar with the relevant information, so instead they turned immediately to other pages or left the platform.

Similarly, for path 3 (i.e., Front - > Index - > Help System) the abandonment rates were higher than normal (i.e., 65.3 %). In this case, since the help system requires time and input from the users, it could be that learning therapists did not enter the help system unless they had enough time to insert the details of a child in mind.

All in all, these results only partially support hypothesis 3, stating that the platform will be fully implemented by learning therapists reaching it via all possible online paths (i.e., links).

3.4. Maintenance

To test hypothesis 4 (Maintenance): Data on platform usage in different time-segments (i.e., 01.01.23–31.03.23 vs. 01.04.23–30.06.23) was compared using the Matomo analytics software. The results are shown below in Table 3. These results support hypothesis 4, stating that therapist content usage will change over time, as indicated by comparing platform usage in different time-segments (i.e., 01.01.23–31.03.23 vs. 01.04.23–30.06.23). Within the sample of $N = 8,459$ LONDI visits, $n = 3,202$ and $n = 5,257$ were in the first and the second time segment, respectively. Notably, we only included Germany and Austria in this table as most users were situated in these countries. Likewise, we only included the most used devices (i.e., desktops and smartphones), and software (i.e., Windows, Mac, iOS, Android). We found that in the first time-segment (i.e., 01.01.23–31.03.23) most visits per local time were between 09:00–19:00 (i.e., 76 %); and that in the second time-segment (i.e., 01.04.23–30.06.23) most visits per local time were between 09:00–21:00 (i.e., 79.6 %).

4. Discussion

The present study aimed to evaluate a German learning disorders platform, by testing hypotheses based on four of the RE-AIM framework dimensions (i.e., Reach, Adoption, Implementation and Maintenance). Specifically, the evaluation focused on the pages for learning therapists and on the help system section of the LONDI platform. Notably, the LONDI platform was developed to combat the educational difficulties and psychological stress affecting children with persistent learning disorders. To this aim, the platform supports relevant user groups by providing information and resources to recognize learning difficulties as early as possible, and for professionals to find effective supporting measures. The platforms' user specific content and algorithm-based help system set LONDI apart from other sources. However, in the context of the German speaking population interested in learning disorders, valuable online resources could be found elsewhere. For example, the websites of the Federal Association for Dyslexia and Dyscalculia [57], and the professional association for integrative learning therapy [58]. Nevertheless, the current study's findings support the notion that LONDI adds a valuable contribution in this context. This is supported, for instance, by the relatively large number of learning therapists using LONDI of their own volition, hence, potentially, leading learning therapists to integrate the platform in daily practice (e.g., routinely opening the information for learning therapists page to retrieve the LONDI protocol sheet for meetings with parents). Moreover, the study has implications for future evaluations in other contexts, as it paves the way for more studies to utilize web analytics for theory-grounded evaluation research. Insights concerning each RE-AIM dimension are detailed below.

4.1. Reach

With regards to hypothesis 1 (Reach), we found that LONDI managed to reach a large proportion of learning therapists (17.53 %), that is much greater than the proportion in the general German population (<0.0001 %). A similar Reach evaluation was utilized by Fuller et al. [41], measuring the number of users using a digital health tool. Nevertheless, as outlined by Lee et al. [29], retaining reach

Table 3
Platform usage in different time-segments

Matrix	T1	T2	Difference (%)
Number of users	3.202	5,257	64 %
Users located in Germany	2,483 (77.5 %)	4,201 (79.9 %)	69 %
Users located in Austria	83 (2.6 %)	101 (1.9 %)	22 %
Avg. time spent on platform	3 min 2s	1 min 46s	−42 %
Avg. time spent on help system	1 min 10s	30s	−57 %
Avg. time spent on therapists info	52s	1 min 28s	69 %
Avg. number of actions	4.4	3.2	−27 %
Time of the day with most visits	14:00 (8.6 %)	14:00 (7.6 %)	0 %
Visits via desktops	1,455 (45.4 %)	1,536 (29.2 %)	6 %
Visits via smartphones	1,592 (49.7 %)	3,537 (67.3 %)	122 %
Visits via Windows	737 (23 %)	814 (15.5 %)	10 %
Visits via Mac	398 (12.4 %)	375 (7.1 %)	−6%
Visits via iOS	298 (9.3 %)	811 (15.4 %)	172 %
Visits via Android	276 (8.6 %)	748 (14.2 %)	171 %

Note. T1 and T2 stand for the first and second time-segments: 01.01.23–31.03.23 and 01.04.23–30.06.23, respectively.

to specific user groups may be challenging, and requires continuous resources and effort. Future efforts will be devoted to continuously attract learning therapists to use LONDI (e.g., via online marketing). Consequently, future evaluations should examine whether LONDI's learning therapists' reach is retained over longer periods of time.

4.2. Adoption

With regards to hypothesis 2 (Adoption), we found that most users intend to continue using the help system. However, we acknowledge that this finding should be interpreted cautiously. Firstly, intention to use was measured by a single self-reported item to make the questionnaire as brief as possible, and it is based on a relatively small sample ($N = 150$). Consequently, it is possible that there was a bias. Namely, that different aspects of the intention to use were lost due to brevity, or that only those interested to continue using the help system answered the item. Secondly, users answered the questionnaire after using the help system but before receiving its recommendations. The placement before the recommendations was deliberate, chosen to maximize the number of users choosing to fill out the questionnaire before leaving the help system. However, it is possible that this placement influenced ratings. Nevertheless, valuable insights regarding Adoption could be deduced. Specifically, we found that users rate the help system as above average in terms of its pragmatic qualities (e.g., how efficient it is), and as good in terms of its hedonic qualities (e.g., how interesting it is). Future efforts will be devoted to further improve the pragmatic qualities (e.g., make the help system less complicated). Interestingly, when we checked if the pragmatic or hedonic qualities predict intention to use, we found that only pragmatic qualities predict it. Similarly, Merkt et al. [26] showed that when it comes to online educational videos, adoption is related to their content and not their features (i.e., film cuts). Thus, the results suggest that pragmaticism is a key motivator for online educational and professional usage. This further supports our decision to try to improve the help system's pragmatic qualities.

4.3. Implementation

With regards to hypothesis 3 (Implementation), we found that paths leading to the pages meant for learning therapists differ in continuation (i.e., conversion) and abandonment rates. Among the six examined paths, two of the paths had bad abandonment rates (i.e., too low or high) according to marketing benchmarks [52]. Notably, path 5 had the highest abandonment rates (74.5 %). It could be that the high abandonment rates were related to the fact that the path has more than two steps. However, they could also be related to potential technical barriers. Future efforts will be devoted to further investigate this path and improve possible technical issues impacting the abandonment rates (e.g., increasing smartphone friendliness). Nevertheless, since the benchmarks were taken from the marketing realm, these abandonment rates might not be bad when examined in the context of the platform. A learning disorders platform such as LONDI is likely to have different standards than a commercial website. Adequate implementation should be assessed in light of an intervention's or in this case a platform's purpose, as advocated by Yardley et al. [59] and Metz et al. [17]. Moreover, high abandonment rates could indicate that a page is not relevant, or rather that users have sufficient knowledge and the content is no longer necessary [59]. Additionally, abandonment rates should be interpreted differently for different pages within the same website. For example, a page solely containing links to other pages with the goal of directing people (e.g., 'are you looking for information on Dyscalculia') might have higher abandonment rates than pages with detailed information. That might have been the case in path 3, which had an abandonment rate of 65.3 % (see Table 2). This path contained the index page, a page meant to direct learning therapists to detailed information or to the help system. Its abandonment rate is the highest compared to paths 2 and 6 that also lead to the help system either from the front page or the information page, with rates of 44.1 % and 51.5 %, respectively.

Interestingly, the maintenance measurements comparing the first three with the last three months revealed a decrease in the average time users spent on the help system (i.e., 1 min 10s vs. 30s). Conversely, there was an increase in the time spent on the information for learning therapists page (i.e., 52s vs. 1 min 28s). The time needed to use the information page is hard to approximate, as it includes various sub-sections that can be read separately. However, for the help system, it can be approximated that for experienced learning therapists, the process of filling out the required fields takes about 5 min per recommendation. As the average time spent on the help system is much lower, especially in the last three months, it could be that learning therapists left the help system without using it. It is also possible that visits to the help system were made for the purpose of finding out what information is needed to get a recommendation for a specific child in mind (e.g., test results).

Furthermore, to better understand if users actually read the content or use the help system, future efforts will also be devoted to setting time goals. Specifically, a goal will be timed depending on how long it should take users to use a feature or read content, based on average word per minute reading speed [60]. If this time elapsed, not counting the time a page is minimized, a goal counts as complete (i.e., a conversion). For example, a time goal for using the help system will count as a conversion if users have stayed in the help system for more than 3 min. Conversely, a time goal for using the information pages will already count as a conversion if users have stayed on the page for more than 1 min. All in all, further research examining abandonment rates for theory-grounded scientific evaluations is needed, and should be interpreted contextually.

4.4. Maintenance

With regards to hypothesis 4 (Maintenance), several interesting findings emerged. On the one hand, when we compared the number of users using LONDI in the first three vs. the last three months, we saw an increase of 64 % in the number of users (i.e., 3.202 vs. 5,257). This is somewhat encouraging, and stands apart from other evaluation studies that found an inverse maintenance pattern (e.g., [34]). On the other hand, when we compared the average time spent on the platform and number of actions, we saw a decrease of

42 % and 27 %, respectively. A possible explanation could be that many of the visits in the last three months were by returning users. Since Matomo keeps users' IP addresses anonymous, we could not test this assumption. Nevertheless, it is likely that returning users spend less time on the platform as they are familiar with its content and structure. A future evaluation could add an item in the demographic questionnaire, asking users if they have used the platform before. An alternative or additional explanation could be that many of the visits in the last three months were done by smartphones (i.e., 49.7 vs. 67.3 % in the first and last three months, respectively). According to Kamerer [14], smartphone visits are typically shorter than desktop visits. These visits usually have a specific purpose, and users are less inclined to do more content exploration. Moreover, when pages are not well suited for smartphone usage, users are more likely to get frustrated and leave a page. Therefore, future efforts will be devoted to further optimize LONDI for smartphone usage.

4.5. Limitations

The current study is not without limitations. Firstly, as underlined by Howe et al. [20], it is impossible to know from web analytics if users actually read content. Thus, it is impossible to know from our Matomo data if learning therapists read the content in their designated information page. However, considering the relatively low abandonment rates from this page, it is likely that its content was regularly read. Moreover, future endeavors will be devoted to setting time goals based on average word per minute reading speed [60], to examine if users surpass the minimum required time to read a page. Secondly, due to Matomo's compliance with strict data protection laws, all users remain anonymous. This means that it is not possible for us to deduce which of the users are first time users, and which are returning users. Moreover, the current study's users did not participate in an experiment nor shared their contact information. Thus, it was not possible to incorporate qualitative complementing methods such as the mixed-method approach by Metz et al. ([61]; e.g., incorporating a thinking aloud method). Nevertheless, the other parts of the larger LONDI evaluation project provide complementing data (e.g., via interviews; [42,43]). Moreover, the various matrices collected by Matomo (e.g., average time spent on the platform in different time periods) and our additional questionnaires (e.g., asking users if they intend to use the help system again) provide valuable insights and a foundation for further improvements. Thirdly, due to limited resources, platform users could not interact with a live person (e.g., via a live chat). Future efforts will be devoted to creating a conversational agent (Chatbot; [62]) as a means of providing user support and measuring user engagement.

5. Conclusion

The current study evaluated the German learning disorders platform LONDI. The platform evaluation was grounded on the RE-AIM framework, and utilized questionnaires and web analytics. Overall, the study's results revealed that the LONDI platform adds a valuable contribution to German speaking learning therapists. Specifically, the platform reached a large proportion of the targeted user group of learning therapists. Future efforts will be dedicated to examine whether this reach is retained over time. Moreover, users reported that they intend to adopt the platform's help system, and this intention was predicted by its pragmatic but not by its hedonic qualities. Future efforts will be dedicated to further improve the help system's pragmatic qualities. Additionally, we saw that the pages intended for learning therapists were implemented in various ways, as indicated by their conversion and abandonment rates. Notably, this interpretation was based on marketing research, which has a different context than that of the current evaluation, and future efforts are needed to further investigate usage in a health-related educational context, and to examine whether users spend enough time on specific pages to count them as read. Finally, we saw that usage patterns are not maintained over time. Most strikingly, increases in users and smartphone usage coincided with decreases in usage time and number of actions. This could be attributed to the fact that smartphone visits are typically shorter than desktop visits. Alternatively, it could be that over time users return to the platform for shorter visits. Future efforts will be dedicated to optimizing smartphone compatibility, and investigating the proportion of returning users. Overall, while it was evident that the platform reached the learning therapists user group, and that they intend to use it, further investigations and improvements are needed. The current study provides a basis for informed policy and funding decisions regarding a health-related educational platform. Furthermore, it paves the path for further theory-grounded online platform evaluations, combining self-reports with web analytics.

CRediT authorship contribution statement

Lior Weinreich: Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Gido Metz:** Writing – original draft, Methodology, Conceptualization. **Björn Witzel:** Conceptualization. **Olga Hermansson:** Conceptualization. **Paula Dümig:** Conceptualization. **Gerd Schulte-Körne:** Supervision, Resources. **Kristina Moll:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Data and code availability

Data will be made available on request.

Ethics statement

This work was approved by the ethics committee at the university hospital LMU Munich [approval number 22–0300 1 V].

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e39968.

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Appendix A: Manuscript

Experimental Investigations of Social Exclusion Among Adolescents with Psychiatric Disorders: A Systematic Review

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Experimental Investigations of Social Exclusion Among Adolescents with Psychiatric Disorders: A Systematic Review

Abstract

Social exclusion is a form of bullying that can lead to various negative consequences, and even extreme forms of violence. Certain groups, such as people with poor mental health and adolescents, are particularly vulnerable. This paper features a systematic review of experiments that investigated the impact of social exclusion on adolescents with psychiatric disorders. Experiments were searched via: PubMed, Web of Science, PsycInfo, ERIC, Cochrane, and a manual search. The search yielded 174 experiments, and 12 remained after screening. These met the inclusion criteria, which included: having an empirical design, participants aged 10-19, and a clinical sample with at least one psychiatric disorder. Among the clinical samples, the most common disorder was depression, featured in seven experiments. The most common paradigm was Cyberball. Results showed that social exclusion impacts adolescents with psychiatric disorders differently than inclusion (e.g., leading to a more negative mood). However, the difference in the impact of social exclusion on adolescents with vs. without psychiatric disorders was only conclusive via fMRI measurements. Compared to healthy controls, adolescents with psychiatric disorders seem to display altered neural reactivity during social exclusion. Based on identified research gaps, future studies are needed to explore the impact of social exclusion on adolescents with a wider range of psychiatric disorders. Other recommendations are included, such as a brain region check list for future experiments using fMRI.

Key words: Social Exclusion, Adolescents, Psychiatric Disorders, Mental Disorders

Introduction

Social exclusion is an umbrella term, which usually refers to bullying through exclusion from social relationships, occasionally accompanied by statements of dislike [1]. Rejection, on the other hand, is a term that refers to exclusion from a group by either being teased, ignored, or experiencing unrequited love [2]. Ostracism, conversely, is a term that refers to exclusion done without any explanation or indication of negative intentions (i.e., being ignored with no apparent reason; 3). Despite these distinctions, in the vast body of research investigating the impact of social exclusion, these terms are often used interchangeably [3]. The current systematic review will use the term social exclusion predominantly, to denote exclusion from a social group of peers.

But why is social exclusion vastly researched? In other words, why is it important? According to the evolutionary perspective, social exclusion plays a vital role in social relationships that, in turn, impact survival [3]. This claim is detailed in the theoretical work by MacDonald and Leary [4]. Their work centers around the notion that social exclusion causes a condition of discomfort. This discomfort shares certain neural response patterns, such as greater activation in the anterior cingulate cortex, with pain caused by physical injuries [5]. Thus, it is often referred to as "social pain" (6; for a critical perspective on this see 7, 8). When social animals experience the so-called "social pain", it prompts them to react against threats to inclusion. For humans, inclusion in supportive social relationships promotes survival [9]. Moreover, MacDonald and Leary [4] give examples from monkey studies, which demonstrate that monkeys that form strong social relationships are more likely to survive and reproduce (e.g., 10). The authors stress that similarly to monkeys, identifying social exclusion and reacting to it was key to our ancestors' survival.

Furthermore, being socially excluded can lead to various negative consequences, such as threats to one's self-esteem [11], increased risk at developing both internalizing and externalizing problems [12], reduction in prosocial behavior, and an overall induction of a negative emotional state [13–15]. Moreover, social exclusion can leave adolescents with the sense that they have been unjustly humiliated, leading to feelings of embitterment [16]. One alarming possible consequence is violent behavior. In fact, the association between social exclusion and violent behavior has been supported in experimental settings [1]. Notably, violent affinity tends to be at its peak during adolescence [17]. Leary et al. [2] demonstrated that chronic rejection, by either being socially excluded, bullied, or experiencing unrequited love, is a common denominator in adolescents that committed school shootings. Their findings suggest that social exclusion on its own is usually not a risk factor. However, combined with one or more of the risk factors for school shooting (i.e., interest in weapons, psychiatric

disorders, fascination with “dark themes” like death and Satan) can lead to violent behavior towards peers. For example, in 1997, 14-year-old Michael Carneal, a teen with a history of psychiatric difficulties, shot and killed three peers and injured five others. After the shooting he reported feeling rejected and disrespected at school. Strikingly, the first person he shot was the object of his unrequited love [18]. Survivors of school shootings, on the other hand, often suffer from negative outcome such as academic difficulties and an increased risk of major depression [19, 20].

Some individuals, such as people with poor mental health, are more vulnerable to the negative consequences of social exclusion. For example, Seidl et al. [21] showed that adults with a borderline personality disorder (BPD) reported a lower sense of belonging, meaningful existence, self-esteem, and control after being ostracized compared to a control group. The authors explained this by the reinforcement of pre-existing interpersonal difficulties. Moreover, Reinhard et al. [22] proposed a “vicious cycle”, wherein having psychopathologies increases the likelihood of social exclusion, which in turn increases symptom manifestation.

Additionally, age seems to play a role in social exclusion vulnerability, as demonstrated by studies comparing adolescents to other age groups. For example, Sebastian et al. [23] compared healthy adolescents and adults (i.e., with no history of neurological or psychiatric disorders), and found that following social exclusion adolescents reported a greater negative mood. The authors explained this by the fact that the ability to regulate distress caused by social exclusion and its related neural functions are developing during life’s second decade. Furthermore, during adolescence, peer-perceived status plays a powerful role [24]. This corresponds with the developmental trajectory of preferred companionship [25]. According to this trajectory, throughout late childhood and adolescence, there is an incremental shift from the preferred companionship of family members to that of peers.

Adolescents with psychiatric disorders are particularly vulnerable to social exclusion, which even in mild cases, increases the likelihood of symptom manifestation (e.g., 26). This could be explained by the “vicious cycle” Reinhard et al. [22] proposed. Specifically, ample research has shown that adolescents with psychiatric disorders (e.g., anxiety, depression, ADHD, etc.) are more likely to suffer from bullying victimization by their peers (notable examples include 11, 27–32; for systematics reviews see 33, 34). In turn, being bullied during adolescence increases the risk of psychiatric disorders (e.g., eating disorders and depression, for systematic reviews see 35–37). Furthermore, a history of being bullied can increase negative affective responses and neural sensitivity to social exclusion [38–40]. Thus, further perpetuating the above-mentioned “vicious circle”.

Cyberball is the most commonly used paradigm for the experimental investigations of social exclusion among adolescents [41]. Cyberball was developed by Williams & Jarvis [42], and has been used in numerous experiments since its launch. Essentially, it is a ball tossing computer game. Participants are made to believe that they are playing with other players. The other players, in fact, are controlled by the experimenters. According to pre-decided conditions, the experimenters could induce social exclusion or inclusion, by preventing or allowing the ball to be passed to the participants. This seemingly simple paradigm has produced profound effects in multiple experimental investigations of social exclusion among adolescents (e.g., 43). However, most of these experiments used a sample of typically developed adolescents [41]. Consequently, the effects of social exclusion on adolescents with psychiatric disorders are under-researched, although they are particularly vulnerable [34].

The objective of the current study is to systematically review experimental investigations of social exclusion among adolescents with psychiatric disorders. To the best of our knowledge, this has not been done before. The noteworthy systematic review by Beckman et al. [33], found an overall higher prevalence rate of cyberbullying in studies investigating children with neurodevelopmental disorders. Another noteworthy systematic review by Alhaboby et al. [44], found an overall higher risk of bullying victimization and psychiatric impact (i.e., mainly depression) in studies investigating adults with chronic conditions and disabilities. Moreover, the important systematic review by Reinhard et al. [22] contributed to the understanding of the manner in which adults with psychiatric disorders are impacted by social exclusion. Nevertheless, the above-mentioned reviews either did not distinguish social exclusion from other forms of victimization, or did not distinguished adolescents from other age groups.

In accordance with the PRISMA statement (45; see Appendix for a filled-out checklist), the Population, Intervention, Comparison, Outcomes, and Study (PICOS) parameters were defined for the included experiments. Specifically, the population was comprised of adolescents with psychiatric disorders, with a mean age between 10 and 19 years old, and with no geographical restriction. Moreover, the sample characteristics were detailed separately for the clinical and control groups in terms of type of disorder, age, and gender. The study intervention (i.e., experimental paradigm) was social exclusion. Additionally, the type of paradigm, the experimental design, and the conditions were detailed. The comparison was between conditions (i.e., social exclusion vs. inclusion / baseline). The outcomes were: (a) impact of social exclusion (i.e., social exclusion vs. inclusion / baseline), and / or (b) impact on clinical vs. control sample.

Methods

Protocol

The review follows a pre-defined protocol (see Appendix). Like the systematic review by Beckman et al. (2020), the protocol begins with the study aim. It then continues with other items mentioned in the PRISMA checklist that should be reported in a systematic review [45]. These items are: the eligibility criteria, information sources, study selection, data collection process, data items, risk of bias in individual studies, and search strategy.

Inclusion and Exclusion Criteria

The inclusion criteria for the experiments used in the final synthesis were: (a) empirical studies written or translated to English; (b) published as journal articles or dissertations; (c) the sample included a clinical population of adolescents aged 10-19 (i.e., the age range for adolescence defined by the World Health Organization; 46), with at least one psychiatric disorder; (d) social exclusion was experimentally induced; (e) the outcome data was on the impact of social exclusion vs. inclusion or a baseline condition.

The exclusion criteria for the experiments used in the final synthesis were: (a) studies that did not meet our inclusion criteria (e.g., non-empirical); (b) the sample mixed adolescents with other age groups, and the different age groups were not analyzed separately; (c) the outcome data was on the impact of witnessing social exclusion rather than experiencing it.

Procedure

The procedure follows a pre-defined protocoled search strategy (see Appendix). Databases for health-care, behavioral, social, biomedical, educational and life science were searched. Specifically, the used databases were: PubMed, Web of Science, PsycInfo, ERIC, and Cochrane. Additional records were also identified through Google Scholar and reference search. The search started on May 3rd 2023, and ended on November 11th 2023. There was no defined starting date for publication. All included experiments were published before the search ended. One exception was an experiment that was first included as a preprint, and published at a peer-reviewed journal at a later point [47].

Results

Study Selection

The initial search yielded 174 records. After deduplication, 120 records remained. The abstracts of these records were read by the first author, leading to the exclusion of 100 records due to irrelevance to the current topic. The full texts of the remaining 20 records were read by first and last authors. Each of these authors

independently evaluated which of these records fulfilled the inclusion criteria. Both authors fully agreed on the 12 included records, as well as on the excluded records. Eight records were excluded for the following reasons: the sample mixed adolescents with other age groups, and the different age groups were not analyzed separately [48–52]; the outcome data was on the impact of witnessing social exclusion rather than experiencing it [53, 54]; the sample did not include a clinical population but rather the experimenters evaluated clinical traits [49, 55]. For an illustration of this process please see Fig. 1.

[insert Fig. 1
here]

Study Characteristics

For a summary of the study characteristics please see Table 1.

Population. Taken together, all 12 included studies had a combined sample size of 758 participants. The smallest sample size was $N = 26$ [56], and the largest was $N = 126$ [57]. The youngest mean age (*M*age) among adolescent participants was 12 years old [58], and the oldest was 17 years old [59]. Among the 12 included studies, the most investigated psychiatric disorder was depression, with or without non-suicidal self-injury (NSSI), prior suicide attempt, and a comorbid borderline personality disorder (BPD). Specifically, depression was the common denominator in the clinical groups in seven studies [47, 57, 59–63]. Two other studies investigated clinical groups with autism spectrum condition (ASC; 56, 64). The remaining three studies investigated clinical groups with other disorders. One study focused on attention deficit hyperactivity disorder (ADHD; 58), and another focused on BPD (65). Lastly, Latina et al. [66] focused on various psychiatric disorders and mental health conditions (i.e., NSSI, depression, social phobia, eating disorders, trauma, paranoid schizophrenia, emotional disorders, and multiple diagnoses), which they grouped under the umbrella term "emotional dysregulation".

Intervention (Experimental Paradigm). Among the 12 included studies, the most used paradigm was Cyberball [42], in combination with or without other paradigms. Specifically, Cyberball was used to induce social exclusion in 10 studies [47, 56–62, 64, 66]. The remaining two studies investigated social exclusion with script-driven imagery [65] and an interactive chat room task [63].

Comparison. All 12 included studies compared the impact of a social exclusion condition with that of an inclusion condition (e.g., in Cyberball by preventing or allowing a ball to be passed to participants). Four studies also included comparisons with a quasi-baseline condition (e.g., in Cyberball by having participants passively

watch the game before playing; 56, 59, 60, 62). Notably, Latina et al. (2023) focused on the comparison between the impact of the commonly used paradigm Cyberball [42], to their newly developed task called Simulated On-Line Ostracism (SOLO).

Outcomes. Among the 12 included studies, the most used behavioral and neurophysiological outcome measurements were the Needs-Threat-Scale (NTS; 67) and functional Magnetic Resonance Imaging (fMRI), respectively. The NTS was used in five studies [47, 56, 59, 60, 64], to assess the impact of social exclusion on participants' self-reported sense of belonging, self-esteem, control, and meaningful existence. fMRI was used in eight studies [47, 57, 59–61, 63–65], as a measure of neural correlates associated with social exclusion. In the reviewed fMRI studies, within-subject contrast maps were typically derived using block-designed models (e.g., exclusion block > inclusion block, exclusion block > baseline block). Moreover, between-subjects differences in brain activation patterns (e.g., depression > HC) were further explored. Other notable outcome measurements included changes in heart rate and heart rate variability [66], as well as participants' performance in an emotion recognition task [62]. Only four studies assessed identical measures before and after the inclusion / exclusion manipulation [56, 58, 62, 66].

Study. All 12 included studies employed a within-subject cross-sectional design. All studies apart form one [62] matched the clinical group with a healthy control group. Six studies were conducted in Germany, five in North America, and one in the UK.

[insert Table 1 here]

Quality Assessment

A quality assessment to evaluate the risk of bias in individual studies was done using the Newcastle-Ottawa scale [68]. This scale evaluates the quality of non-randomized studies using a star system, with a higher number of stars indicating a higher assessment of quality (for more details about the scale, please see the appended protocol). Notably, none of the included experiments received a star for case representativeness. However, this could be deemed reasonable, as the samples included clinical populations, and participants were most likely inpatients in the various institutes the experimenters were affiliated with. Most experiments scored high scores (i.e., between five to seven stars out of a total of nine), indicating a lower risk of bias. Two experiments scored lower scores (i.e., three or four stars), indicating a higher risk of bias [65, 66]. In these experiments, there was no adequate case definition. Moreover, the control groups' selection and definition were inadequate. Additionally, in Latina et al. [66], comparability with the clinical group was inadequate.

Nevertheless, all studies fulfilled the inclusion criteria. For a summary of the quality assessment across each of the studies please see Table 2.

[insert Table 2 here]

Results of Individual Studies

General Effects of Social Exclusion. For self-report measures, most studies found a negative association with social exclusion on questionnaires such as the NTS [56, 60, 64]. This was also the case with the Positive And Negative Affect Schedule for Children (PANAS-C) (58), and the anxiety measures State / Trait Anxiety Inventory (STAI-S / STAI-T) [56]. However, several studies only administered these measures post-manipulation and compared groups, making it impossible to conclude whether group differences were pre-existing or resulted from groups' differential sensitivity to exclusion (e.g., 47, 59). Additionally, one study did not find an association with social exclusion on self-report measures [65], but that might be due to the used paradigm (i.e., script-driven imagery). In this paradigm, participants had to listen to a script and imagine the described scenes as vividly as they can. Thus, the extent of experienced social exclusion depends on the power of imagination of the individual. Therefore, it is possible that due to the nature of the task, social exclusion was not experienced as vividly as it would have had the researchers used another paradigm (e.g., Cyberball). Moreover, one study only compared two different exclusion paradigms [66]. This made it impossible to deduce the separate impact of each paradigm. In this study, heart rate and heart rate variability were assessed, but only the relative effect of two exclusion paradigms was reported [66]. Another study, that did not have a healthy control group but rather adolescents with low or high depressive symptoms, showed an effect using an emotion recognition task [62].

The eight studies using fMRI reported various contrasts (inclusion > exclusion, inclusion > baseline / observation), which showed activation in various brain areas. Several of these areas have previously been associated with social exclusion, such as the insula (anterior: 60, 61, 64; left: 47), anterior cingulate cortex (60; pregenual / dorsal: 59; perigenual: 57; subgenual: 64), prefrontal cortex (ventrolateral / dorsolateral: 59, 64; medial: 57), ventral striatum [59, 69], and inferior frontal gyrus (left / right: 47, 57). Moreover, Gifuni et al. [47] found an association between lower insula activation and lower feeling of belongingness, indicating that activity in this brain region might play a key role in establishing the feeling of "being connected" with others.

Adolescents With Depression. Results among the studies that focused on the impact of social exclusion on adolescents with depression varied. Results from behavioral measures were ambiguous: whereas the post-exclusion NTS indicated higher distress levels for the clinical group in one study [47], in other studies [59, 60] the NTS showed no such effects. Silk et al. [63] showed that the clinical group reported being more "sad",

"nervous" and "excluded", and less "happy" compared to healthy adolescents. Similarly, Müller et al. [62] showed that adolescents with depression identify emotions in ambiguous faces differently depending on their symptoms' severity. Specifically, they showed an interaction effect, wherein "high depression" adolescents exhibited the highest perceptual sensitivity to happy faces depicted by an excluder, compared to includer and stranger models, the inverse pattern of "low depression" adolescents. The fMRI group contrasts showed that compared with healthy controls, adolescents with depression had higher exclusion-related neural activation in the insula [47, 57, 61, 63], subgenual anterior cingulate [63], putamen [59], left occipital operculum [61], and inferior frontal gyrus [57]. Hypersensitivity of this brain network may be related to enhanced salience and an emotion regulation bias in adolescents with depression [70, 71]. Moreover, the addition of NSSI led to prefrontal cortex activation [59, 60], but conversely *lower* exclusion-related activation in the inferior frontal gyrus (and right middle / superior frontal gyrus) reported by Gifuni et al. [47], who also reported lower precuneus activation, as did Mellick et al. [61]. The prefrontal cortex plays a crucial role in emotion regulation [72]; modulations of activity in these brain circuits might indicate altered neural processing of social exclusion that is related to the absence or presence of NSSI [60].

In sum, studies focusing on adolescents with depression found that social exclusion impacted them differently than inclusion, and found some differences in the impact on them compared to healthy adolescents, particularly in the insula.

Adolescents With Autism Spectrum Condition (ASC). Both studies that focused on adolescents with ASC found that they were impacted by social exclusion. The results from behavioral measures (i.e., NTS, STAI-S) obtained by Sebastian et al. [56] showed that adolescents both with and without ASC self-reported more negative needs and anxiety following social exclusion compared to baseline and inclusion. Conversely, they showed that neurotypical adolescents, but *not* adolescents with ASC, had a decreased mood following social exclusion. In contrast, Masten et al. [64] found no group differences using the NTS. However, their fMRI results showed that compared to neurotypical adolescents, adolescents with ASC had less neural activation in the subgenual anterior cingulate cortex, anterior insula, ventrolateral prefrontal cortex, and ventral striatum following social exclusion vs. inclusion; thus, individuals with ASC showed less neural activity in brain regions that have previously been associated with distress and distress regulation during social exclusion [6, 73]. This finding is in line with previous research showing that individuals with ASC show hypoactivation in brain regions that have been linked to emotion processing [74].

In sum, as with depression, studies focusing on adolescents with ASC found that social exclusion impacted them differently than inclusion, and found some differences in the impact on them compared to healthy adolescents.

Adolescents With Other Psychiatric Disorders. Results among the studies that focused on the impact of social exclusion on adolescents with other disorders varied considerably. In terms of social exclusion's impact, the results obtained by Hartmann et al. [58] provide partial support to the impact of social exclusion. Moreover, the results obtained by Krauch et al. [65] and Latina et al. [66] provide no support or are not reported. Specifically, Hartmann et al. [58] compared adolescents with loss of control eating or ADHD with healthy adolescents. They found an interaction effect for group by time in impulsivity (i.e., impulsivity increased with time) but not in self-reported affect following social exclusion. Krauch et al. [65] focused on adolescents with BPD and found that self-reported measures (e.g., subjective anger ratings) were not affected by social exclusion. However, they induced social exclusion via script-driven imagery, which might be less powerful than other paradigms such as Cyberball. Furthermore, although fMRI was measured throughout the experiment, the conditions' neurophysiological impact is unknown as they only reported results concerning group comparisons. Latina et al. [66] focused on adolescents with various psychiatric disorders (i.e., grouped under the umbrella term "emotional dysregulation"). Similar to Krauch et al. [65], they too only reported results concerning group comparisons. In terms of group differences, Hartmann et al. [58] found no differences between adolescents with loss of control eating or ADHD and healthy adolescents. Krauch et al. [65] found some self-reported differences between adolescents with BPD and healthy adolescents (i.e., higher dissociation), as well as differences in neural activation. Latina et al. [66] found both self-reported and psychophysiological differences between adolescents with emotional dysregulation and healthy adolescents. However, their focus was not on the impact of social exclusion, but rather on the comparison between different social exclusion paradigms (i.e., SOLO vs. Cyberball). Moreover, it is possible that these paradigms were not comparable since the social exclusion phase in SOLO includes additional cyberbullying (i.e., which the authors address briefly as name calling and mobbing).

In sum, based on these studies, the impact of social exclusion on adolescents with other disorders was inconclusive and to some extent remains unknown.

Discussion

Summary of Evidence

The aim of the current study was to systematically review experimental investigations of social exclusion among adolescents with psychiatric disorders. This systematic review was done in accordance with the

PRISMA framework [45]. Twelve experiments that met pre-defined inclusion criteria were included. Although the results from these experiments were partly inconclusive, a certain pattern can be deduced. Specifically, both adolescents with and without psychiatric disorders are impacted by social exclusion. Moreover, fMRI measurements provide evidence to an altered neural reaction in adolescents with psychiatric disorders in response to social exclusion. Notably, the included experiments varied considerably in terms of clinical sample characteristics, methodology, and reported results. For a summary of the critical findings please see Table 3.

[insert Table 3 here]

Social Exclusion and Psychiatric Disorders. Among the included experiments, the most researched psychiatric disorder was depression (n = 7), followed by various other disorders (n = 3) and ASC (n = 2; please find detailed information in the "Results of Individual Studies" sub-section). Evidence from the experiments researching both adolescents with depression and adolescents with ASC indicates that social exclusion impacts them differently than inclusion does. Evidence from the experiments researching adolescents with various other disorders (e.g., ADHD) varied considerably. Although there was some support to a different impact of the condition (i.e., social exclusion vs. inclusion), and to group differences (i.e., clinical vs. control group), it is difficult to draw clear conclusions. This difficulty arises from these studies' choice of paradigms (e.g., listening to a script, which might not be powerful enough to elicit social exclusion), and from missing results (i.e., unknown comparisons). Thus, more research is needed investigating a sample with a broad range of disorders in a unified transparent manner. Please see Table 4 for a recommended checklist for future research, as well as implications for clinicians and policy.

ASC is a particularly interesting condition in the context of social exclusion. Namely because individuals with ASC often struggle in social situations with neurotypicals [75]. Interestingly, Sebastian et al. [56] found that after social exclusion, typically developing adolescents, but not adolescents with ASC, had a decreased mood. This stood out from the other experiments included in this review that either showed no difference, or an increased response in clinical populations compared to healthy adolescents. One of the possible reasons for this difference that Sebastian et al. [56] suggested, is the difficulty many adolescents with ASC have in interpreting their own emotional state. Another possibility is that adolescents with ASC struggle with perceiving social exclusion [76]. To examine this, the study by Sebastian et al. [56] could be replicated with an additional measurement of how the situation is being perceived (e.g., the understanding score used by Hodgins et al. [76]) . This suggestion as well as further research with adolescents with ASC could contribute valuable insights.

Moreover, other disorders such as antisocial personality disorder (ASPD) would be a great avenue for future research. ASPD could be particularly interesting in the context of social exclusion, as among other things it is characterized by failure to conform with social norms and a tendency to react aggressively when angry [77]. Notably, ASPD is not diagnosable before the age of 18. This means that there is only a one-year time frame left to test adolescents with ASPD (i.e., before they turn 19; i.e., according to the age range for adolescence defined by the World Health Organization; 46). To combat this challenge, adolescents diagnosed with conduct disorder before the age of 15, a pre-requisite for an ASPD diagnosis, could be contacted and potentially recruited in time. One interesting experiment that was excluded from the current systematic review (i.e., since it included older participants, and there was no clinical diagnosis but rather a measurement of traits), examined the impact of psychopathic traits on responses to social exclusion [49]. One of their findings was that participants high on antisocial traits were angrier after being socially excluded. Furthermore, adolescents with psychiatric comorbidity were examined only in some of the included experiments (e.g., adolescents with depression and NSSI; 59). Although psychiatric comorbidity is widely common in developing populations, to date, it is still common practice for clinical research to focus on isolated disorders and exclude participants with additional deficits [78]. Thus, research examining other disorders such as ASPD, as well as research looking into psychiatric comorbidity, could be highly beneficial.

Impact of Social Exclusion on clinical vs. healthy control (HC) samples. Evidence regarding group differences between clinical populations and HC was inconclusive. Specifically, fMRI data showed group differences, but support from behavioral measures was inconsistent. Therefore, it is possible that group differences are most prominent on a neurophysiological level, pointing toward sensitization processes in the brain. According to previous meta-analysis and reviews, the brain regions predominantly related to social exclusion are: the posterior cingulate cortex, posterior insula, anterior insula, anterior cingulate cortex, prefrontal cortex, temporal cortex, precuneus, ventral striatum, inferior gyrus and superior frontal gyrus, and the occipital pole [79–81]. Future studies implementing fMRI should investigate all the above-mentioned brain regions (e.g., by using appropriate regions of interest analyses). Moreover, when using behavioral measures, baseline measurements should be conducted to clearly distinguish between differences related to psychiatric disorders from those caused by social exclusion.

Social Exclusion Paradigms. Among the included experiments, Cyberball [42] was the most commonly used paradigm (n = 10). This is not surprising, since Cyberball is free to use, easy to implement, and has been well-established in research since its early versions for more than two decades. Multiple other social exclusion

paradigms have been developed over the years, including: Get Acquainted [82], Life Alone [1], O-Cam [83], Ostracism Online [84], and social media vignettes [85]. It is possible that these paradigms were not tested on developing clinical populations as the experimenters did not have access to patients in medical institutions. In turn, experimenters with access to patients in medical institutions might have not used these paradigms as they preferred to use Cyberball [42], knowing it is so well-established. One paradigm that has been tested on a developing clinical population is SOLO, developed by Latina et al. [66]. SOLO has high ecological validity, since it simulates being socially rejected in a chat on WhatsApp, a communication platform widely used by adolescents. Although Latina et al. [66] found that SOLO leads to more negative effects than Cyberball, their experiment included additional elements (e.g., name calling), which make the comparison problematic. Future studies using SOLO without these additional elements, or other ecologically valid paradigms, on a sample of adolescents with psychiatric disorders could contribute valuable insights. Please see Table 4 for the implications of the systematic review for practice and policy, and a checklist for future research.

[insert Table 4 here]

Limitations

This systematic review is not without its limitations. Firstly, both a meta-analysis (which would allow the computation of combined effect sizes) and a formal preregistration were not conducted. A meta-analysis was not feasible due to the different nature of the included experiments, which did not allow a comparison of effect sizes. Nevertheless, we believe that the grouping of the included experiments in to three disorder groups allowed for some valuable comparability. Moreover, the systematic review was not preregistered on a public website. However, the researchers followed a pre-defined protocol adhering to the PRISMA statement [45], which is available in the Appendix. Secondly, all of the included experiments had a within-subject design with regard to the experimental manipulation (social exclusion). Moreover, only some included a comparison between social exclusion and a quasi-baseline condition (e.g., passively watching other participants playing Cyberball). This undermines their support to the possibility of causal links between psychiatric disorders and social exclusion [86, 87]. Thus, in some cases it was not possible to deduce the impact of social exclusion, but rather its association with the different measurements. One notable experiment we had to exclude (i.e., as its sample included adults) was by Meneguzzo et al. [52]. In this experiment, a between-subjects design was used to clearly distinguish the impact of social exclusion from that of inclusion on people with eating disorders. Thirdly, gender diversity was compromised, as gender was not equally distributed in the included experiments. In particular, experiments focused on adolescents with depression (e.g., 60) had a predominantly female sample. Conversely, experiments focused on adolescents with ASC had a predominantly male sample (e.g., 64). This is probably related to gender

differences in the prevalence of different psychiatric disorders [88] Nevertheless, future experiments should strive to recruit gender balanced samples. Fourthly, six experiments that mixed adolescents with other age groups were excluded, which might have compromised the findings. We reached out to these papers' corresponding authors if a current email address was available (i.e., five out of the six), and asked if they performed separate analyses for adolescents. One author replied and said they did not, and the others were not responsive. Lastly, we chose a medical approach, which compromises neurodiversity. This was done to clearly distinguish clinically diagnosed samples from control samples, and to draw general comparisons between different disorders. To promote diversity when deemed possible, when describing autistic individuals, we used the term "condition" (i.e., autism spectrum condition and not disorder). This was done in accordance with the prevailing outlook that autism is a difference rather than a disorder [89].

Conclusions

This paper systematically reviewed experimental investigations of social exclusion among adolescents with psychiatric disorders. The review revealed that social exclusion impacts adolescents with psychiatric disorders differently than inclusion, both neurophysiologically and behaviorally (e.g., eliciting a negative emotional state). The psychiatric disorder most included experiments focused on was depression. The difference in the impact of social exclusion on adolescents with vs. without psychiatric disorders was inconclusive. Namely, we found differences between patients and healthy participants with neurophysiological (i.e., fMRI) but not with behavioral measures. Thus, it is possible that group differences are related to altered neural sensitivity and can thus predominantly be observed on the level of brain activity. More research is needed exploring a wider range of disorders associated with social exclusion. Furthermore, more research including baseline measurements and ecologically valid paradigms would be highly beneficial. It is advisable that practitioners treating adolescents with psychiatric disorders screen for social exclusion, and act to prevent its negative impact and potential violent reactions. Lastly, it is recommended that policy makers emphasize social exclusion's negative impact, especially among adolescents with psychiatric disorders, in new and existing anti-bullying programs.

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Table 1

Study Characteristics Summary

Study, intervention & comparison	Population	Outcomes	
		Impact of exclusion	Impact of exclusion on adolescent clinical vs. healthy control (HC) group
Brown et al. (2017) Germany Cyberball Only watching Cyberball (baseline) vs. Inclusion via Cyberball vs. Exclusion via Cyberball	Adolescent depression + non-suicidal self-injury (NSSI): *n* = 13 *M*age = 15.5 10 females Adolescent control: *n* = 15 *M*age = 14.5 12 females Adult depression + NSSI + borderline personality disorder (BPD): *n* = 14 *M*age = 23.6 14 females Adult control: *n* = 17 *M*age = 23.2 17 females	fMRI comparing passive viewing, inclusion, and exclusion showed differential activation in the ventrolateral prefrontal cortex, pregenual anterior cingulate cortex, dorsal anterior cingulate cortex, ventral striatum, and the dorsolateral prefrontal cortex	The Hurt Feelings Scale (HFS) but not the Needs-Threat-Scale (NTS) results showed that adolescents with depression and NSSI self-reported more negative feelings compared to healthy controls (HC), indicating higher general sensitivity for social exclusion fMRI exclusion > inclusion contrasts showed that adolescents with depression + NSSI had higher activation of the putamen compared to both the depression + NSSI + BPD group and HC fMRI exclusion > baseline contrasts showed that adolescents with depression + NSSI had lower activation of the premotor cortex and dorsomedial prefrontal cortex compared to the depression + NSSI + BPD group; but higher activation of the putamen compared to HC, potentially indicating increased neural reactivity (salience network) and more intense negative social feedback processing related to NSSI, consistent with research conceptualizing bullying as a NSSI risk factor [90]
Gifuni et al. (2024) Canada Cyberball + Go-NoGo to measure response inhibition Only watching Cyberball (baseline) vs. Inclusion via Cyberball vs. Exclusion via Cyberball 2 Go-NoGo block types: 3 “Go” blocks 3 “NoGo” blocks	Depression + prior suicide attempt: *n* = 29 *M*age = 16.3 25 females Depression + no prior suicide attempt: *n* = 35 *M*age = 16.0 28 females Control: *n* = 32 *M*age = 15.3 22 females	NTS results showed that adolescents with depression both with and without a prior suicide attempt had lower scores than HC on all subscales (Belonging, Self-Esteem, Significant Existence, Sense of Control) fMRI exclusion > baseline contrasts showed that adolescents with depression + prior suicide attempt had: (1) lower activation in the right inferior frontal gyrus and higher activation in the right middle / superior frontal gyrus compared to adolescents with depression and no prior suicide attempt, and (2) lower activation in the left and right inferior frontal gyri compared to HC; also, (3) adolescents with depression and no prior suicide attempt had a lower activation in the left inferior frontal gyrus and the right middle / superior frontal gyrus compared to HC; consistent with research linking activation differences in these prefrontal brain areas to difficulties in emotion regulation [72] fMRI exclusion > inclusion contrasts showed that adolescents with depression and no prior suicide attempt had lower activation in the right precuneus and bilateral middle frontal gyrus compared to both other groups	

Groschwitz et al. (2016) Germany Cyberball Only watching Cyberball (baseline) vs. Inclusion via Cyberball vs. Exclusion via Cyberball	Depression without NSSI: *n* = 14 *M*age = 15.9 11 females Depression + NSSI: *n* = 14 *M*age = 15.4 11 females Control: *n* = 15 *M*age = 14.5 12 females	The NTS indicated that participants felt excluded and distressed following social exclusion fMRI exclusion > inclusion showed activation in the anterior insula, anterior cingulate cortex, parahippocampus, but also pre-supplementary motor area and secondary visual regions	The RSQ (Rejection Sensitivity Questionnaire) indicated elevated sensitivity to rejection in both depression groups. The NTS results showed no group differences apart from a greater feeling of helplessness among adolescents with depression + NSSI compared to HC; increased sensitivity to social rejection and similar feelings of social exclusion in both depression groups irrespectively of NSSI is consistent with meta-analytical findings that bullying and social rejection seem to be critical risk factors for adolescent depression [87], contributing to a vicious circle of reciprocal influences that further stabilizes the persistence of peer victimization and depressive symptoms [86] fMRI exclusion > inclusion contrasts showed that adolescents with depression + NSSI had greater activity in the medial prefrontal cortex, ventrolateral prefrontal cortex, and parahippocampus, compared to depression without NSSI; for peak voxel activation, differential medial prefrontal cortex / ventrolateral prefrontal cortex activity for depression + NSSI was higher than for both other groups, pointing toward altered processes in brain regions that have been associated with emotion regulation [72]
Hartmann et al. (2013) Germany Stop signal task (SST) + Cyberball SST vs. Exclusion via Cyberball vs. SST	Loss of control (LOC) eating: *n* = 23 *M*age = 12 14 females ADHD: *n* = 33 *M*age = 12.21 11 females Control: *n* = 32 *M*age = 12.13 18 females	Pre- and post-exclusion Positive And Negative Affect Schedule for Children (PANAS-C) showed exclusion increased negative mood only for the LOC eating group compared to the other groups, suggesting that ADHD in adolescents is not associated with enhanced negative emotional responses following social exclusion Impulsivity measurements for the SST showed that exclusion caused a difference in impulsivity between the ADHD and LOC eating groups, with a post-exclusion increase in the LOC group and a decrease in the ADHD group No correlation between mood (PANAS-C) and SST (impulsivity)	
Jankowski et al. (2018) USA Cyberball Cyberball practice (baseline)	Depression: *n* = 87 *M*age: 14.89 50 females Control: *n* = 39 *M*age: 14.43	fMRI exclusion > inclusion showed activation of medial prefrontal cortex / perigenual anterior cingulate cortex, left inferior frontal gyrus, right inferior frontal	fMRI exclusion > inclusion group contrasts showed that adolescents with depression had greater activity in the left anterior insula / inferior frontal gyrus compared to HC, and that HC had greater activity in the left middle temporal gyrus compared to depressed adolescents; anterior insula hypersensitivity may be related to

vs. Inclusion via Cyberball vs. Exclusion via Cyberball vs. Short inclusion via Cyberball	20 females	gyrus, right precentral gyrus, right postcentral gyrus, right superior temporal gyrus / middle temporal gyrus, and bilateral occipital cortex Depressive variables were correlated with neural patters during social exclusion (e.g., greater left middle temporal gyrus activity was positively correlated with self-worth)	heightened salience and an emotion regulation bias in participants with depression [70, 71]; differences in middle temporal gyrus activation may be related to altered emotion regulation in response to negative social information [91] Adolescents with depression recruited anterior insula / inferior frontal gyrus more during exclusion (and middle temporal gyrus to a similar degree) compared to inclusion; whereas HC recruited the anterior insula / inferior frontal gyrus more during inclusion compared to exclusion, and middle temporal gyrus more during exclusion; this corresponded to a significant difference between adolescents with depression and HC in middle temporal gyrus recruitment, but no significant group difference for the anterior insula / inferior frontal gyrus
Krauch et al. (2018) Germany Script-driven imagery 8 scripts read by actors, each with 4 phases: 1. baseline 2. rejection-based anger 3. other-directed/self-directed aggression 4. relaxation	Adolescents with BPD: *n* = 20 *M*age = 16.35 20 females Adolescent control: *n* = 20 *M*age = 15.85 20 females Adults with BPD: *n* = 34 *M*ean age = 25.69 34 females Adult control: *n* = 32 *M*age = 27.33 32 females	Self-reported measures showed that adolescents with BPD did not differ in their reaction to rejection-based anger compared to HC, but did report higher dissociation fMRI showed that during rejection-based anger, adolescents with BPD had higher activity in in a large cluster comprising parts of the left insula, putamen, and claustrum, compared to HC; suggesting that early developmental stages of BPD are associated with an enhanced neural reactivity to rejection-related anger; these findings highlight the need of appropriate early interventions for adolescents with BPD	
Latina et al. (2023) Germany Cyberball + WhatsApp chat simulation (SOLO) Inclusion via Cyberball vs. Exclusion via Cyberball Inclusion via SOLO	Emotion dysregulation: *n* = 23 *M*ean age = 14.74 17 females Control: *n* = 12 *M*age = 16.0 5 females	Self-reported emotional affect was measured before and after each paradigm, but the reported results only include SOLO vs. Cyberball paradigm comparisons (i.e., not between the conditions of each paradigm) Reported heart rate (HR) and heart rate variability (HRV) were measured throughout the experiment, but the reported results only	Self-reported emotional affect results showed that adolescents in the emotion dysregulation group, but not healthy adolescents, had higher negative affect after the SOLO paradigm compared to Cyberball HR and HRV results showed that adolescents in the emotion dysregulation group, but not healthy adolescents, had higher HR and lower HRV during SOLO compared to Cyberball

vs. Exclusion + name calling + mobbing via SOLO		include paradigm comparisons	
Masten et al. (2011) USA Cyberball Inclusion via Cyberball vs. Exclusion via Cyberball	Autism spectrum condition (ASC): *n* = 19 *M*age = 14.0 1 female Control: *n* = 17 *M*age = 13.6 2 females	Self-reported feelings of distress using NTS showed moderate levels of social distress following social exclusion for both groups fMRI exclusion > inclusion showed higher activation in the subgenual anterior cingulate cortex, anterior insula, ventrolateral prefrontal cortex, and ventral striatum for both groups	fMRI exclusion > inclusion contrasts showed that adolescents with ASC had less activation compared to neurotypical adolescents in the subgenual anterior cingulate cortex and anterior insula, areas linked to more distress caused by social exclusion; and at the same time less activation in the ventrolateral prefrontal cortex, an area linked to the regulation of distress caused by social exclusion Although those with ASC showed less neural activity in brain regions previously linked to distress and distress regulation during peer exclusion [6, 73], both groups were equally aware and concerned (i.e., self-reported distress) about peer rejection
Mellick (2017) USA Cyberball Inclusion via Cyberball vs. Exclusion via Cyberball	Depression: *n* = 17 *M*age: 15.53 13 females Control: *n* = 18 *M*age = 14.11 10 females	fMRI exclusion > inclusion contrasts showed that adolescents with depression had higher activation in the right anterior insula, left occipital operculum (this is mentioned in abstract and discussion, but not in the results), and left nucleus accumbens compared to HC fMRI inclusion > exclusion contrasts showed that HC had higher activation in the right precuneus and right middle cingulate gyrus compared to adolescents with depression	
Müller et al. (2017) Germany Emotion recognition task (ERT) + Cyberball ERT 1 week before (baseline) vs. ERT 1 week later after: Inclusion via Cyberball Exclusion via Cyberball	High depressive symptoms (HD): *n* = 26 *M*age: 13.42 15 females Low depressive symptoms (LD): *n* = 34 *M*age: 13.25 25 females	No HC group ERT results at baseline did not indicate a difference between LD and HD adolescents LD and HD adolescents' sensitivity to happy facial expressions differed depending on the role of the person during Cyberball (i.e., includer vs. excluder): LD adolescents were more sensitive to the happy faces of includers and strangers; HD adolescents were more sensitive to the happy faces of excluders, suggesting that depressive symptom severity alters post-social exclusion facial expression sensitivity	
	ASC:		

Sebastian et al. (2009) UK Cyberball Inclusion via Cyberball vs. Exclusion via Cyberball	*n* = 13 *M*age: 16.9 0 females Control: *n* = 13 *M*age = 16.9 0 females	NTS and related mood questions showed that social exclusion negatively affected both groups (compared to baseline and inclusion) State / Trait Anxiety Inventory (STAI-S / STAI-T) showed that state anxiety was lower for both groups after inclusion (compared to baseline and exclusion)	For the NTS, post-ostracism meaningful existence ratings decreased more for adolescents with ASC than for neurotypical controls The mood section of the NTS showed that in neurotypical adolescents, but not in adolescents with ASC, following social exclusion the mood decreased compared to the baseline and inclusion
Silk et al. (2014) USA Chatroom Interact Task (CIT) Participants choose to interact / exclude virtual peers 2 weeks before (baseline) vs. 2 weeks later participants are told that they were included / excluded from an interaction with virtual peers	Major depressive disorder: *n* = 21 Control: *n* = 27 Mean age and gender were not described for each sub-sample, but rather for the whole sample: *N* = 48 *M*age = 15.48 34 females	fMRI showed that adolescents in a more advanced pubertal status had higher activation to social exclusion in both right and left amygdala / parahippocampal gyrus, and the caudate / subgenual anterior cingulate cortex fMRI results showed that following inclusion, the groups did not differ in neural activation	Post-CIT self-reported feelings showed that adolescents with a major depressive disorder reported being more “sad”, “nervous” and “excluded”, and less “happy” compared to HC; groups did not differ in feeling “included” fMRI showed that adolescents with a major depressive disorder had greater activity in the bilateral amygdala, subgenual anterior cingulate cortex, left anterior insula, and left nucleus accumbens compared to HC; neural reactivity to peer rejection seems to be particularly enhanced in youth with depression

Note. Included outcomes only relate to social exclusion and to adolescent participants. Outcomes related to interaction effects were merged to appear in both outcome columns.

Table 2

Quality assessment

	Brown et al. (2017)	Gifuni et al. (2024)	Groschwitz et al (2016)	Hartmann et al. (2013)	Jankowski et al. (2018)	Krauch et al. (2018)	Latina et al. (2023)	Masten et al. (2011)	Mellick (2017)	Müller et al. (2017)	Sebastian et al. (2009)	Silk et al. (2014)
Is the case definition adequate?	★	-	★	★	-	-	-	★	★	★	★	★
Representativeness of the cases	-	-	-	-	-	-	-	-	-	-	-	-
Selection of controls	-	★	-	-	★	-	-	★	★	★	-	★
Definition of controls	-	-	★	-	-	-	-	★	-	-	★	-
Comparability of cases and controls based on the design or analysis	★★	★★	★★	★★	★★	★	-	★	★★	-	★★	★★
Ascertainment of exposure	★	★	★	★	★	★	★	★	★	★	★	★
Same method of ascertainment for cases and controls	★	★	★	★	★	★	★	★	★	★	★	★
Non-Response rate	★	★	★	★	★	★	★	★	★	★	★	★

Note. Based on the Newcastle-Ottawa scale [68]. "★" corresponds with low risk of bias and "-" corresponds with high risk of bias.

Table 3

Summary of the Systematic Review's Critical Findings

Critical Findings
• 12 experiments investigating social exclusion among adolescents with psychiatric disorders were included • All 12 showed that social exclusion impacts adolescents with psychiatric disorders differently than inclusion • The most researched psychiatric disorder was depression, featured in 58% (*n* = 7) of the experiments • 42% (*n* = 5) of the experiments found a conclusive group difference in clinical vs. healthy controls using both behavioral measurements and neuroimaging (i.e., fMRI). All experiments containing fMRI measurements revealed group differences in brain activation, pointing toward altered neural responding in adolescents with psychiatric disorders (e.g., heightened neural reactivity to social exclusion in adolescents with depression) • Cyberball was the most used paradigm, used in 83% (*n* = 10) of the experiments

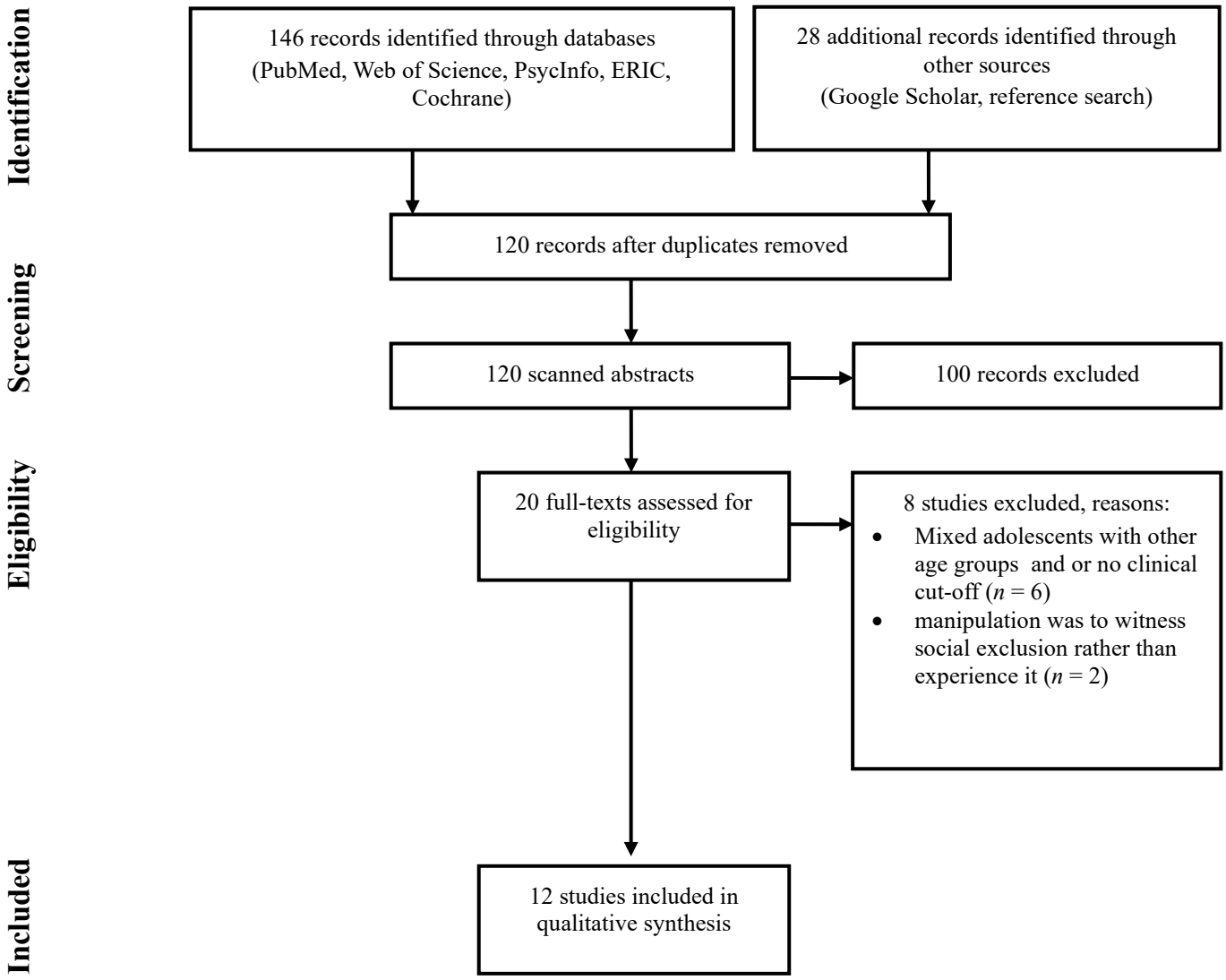
Table 4

Implications of the Systematic Review for Practice, Policy, and Checklist for Future Research

Implications for Practice	Implications for Policy	Recommended checklist for Future Research
When treating adolescents with psychiatric disorders, practitioners should evaluate if they are being socially excluded If yes, practitioners should assist these adolescents in developing strategies to combat negative impacts on their mood and well-being If yes, special care should be taken to identify potential violent reactions to facilitate its prevention	Emphasize social exclusion's negative impact, especially among adolescents with psychiatric disorders in new and existing programs (e.g., anti-bullying programs)	☐ Explore the impact of social exclusion on samples with various disorders (e.g., ASPD) and psychiatric comorbidity ☐ Use fMRI to measure brain regions that have been linked to social exclusion by meta-analyses and reviews (Mwilambwe-Tshilobo & Spreng, 2021; Vijayakumar et al., 2017; Wang et al., 2017): ☐ posterior cingulate cortex ☐ posterior insula ☐ anterior insula ☐ anterior cingulate cortex ☐ prefrontal cortex ☐ temporal cortex ☐ precuneus ☐ ventral striatum ☐ inferior gyrus and superior frontal gyrus ☐ occipital pole ☐ Conduct appropriate baseline measurements ☐ Test ecologically valid paradigms (e.g., SOLO without additional bullying elements)

Fig. 1

Flow diagram of the study selection process



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