Loop(s) of loneliness: Exploring cognitive and behavioral aspects of (mal)adaptive loneliness

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LOOP(S) OF LONELINESS

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LOOP(S) OF LONELINESS

To my dearest, who have always provided a sense of belonging and joy in my life.

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LOOP(S) OF LONELINESS

This cumulative dissertation includes the following three articles:

Article I: Skoko, A., Seewer, N., Mund, M., & Krieger, T. (2024). Revisiting the Cognitive and Behavioral Aspects of Loneliness: Insights from Different Measurement Approaches [Manuscript submitted for publication].

Article II: Skoko, A., Kaeser, J., Seewer, N., & Krieger, T. (2024). Preliminary Investigation of the Regulatory Loop of Loneliness and the Protective Role of Self-Esteem – A Cross-Sectional Study. *Current Psychology*. https://doi.org/10.1007/s12144-024-06185-0

Article III: Skoko, A., Mund, M., Seewer, N., & Krieger, T. (2024). Untangling the Web of Prolonged Loneliness: A Longitudinal Examination of the Cognitive Model of Loneliness [Manuscript submitted for publication].

Article IV: Seewer, N., Skoko, A., Käll, A., Andersson, G., Luhmann, M., Berger, T., & Krieger, T. (2024). Efficacy of an Internet-based self-help intervention with human guidance or automated messages to alleviate loneliness: A three-armed randomized controlled trial. *Scientific Reports*. *14*(1), 6569. https://doi.org/10.1038/s41598-024-57254-0

Abstract

Loneliness is a profoundly distressing state that stems from an innate need to belong. This pervasive feeling has repeatedly been shown to have associations with detrimental physical and mental health outcomes. One prominent cognitive model delves into the cognitive and behavioral components of loneliness, depicting prolonged loneliness as a vicious self-perpetuating cycle. Despite its widespread acknowledgments in the scientific community and some empirical support, significant gaps remain regarding some of its assumptions. Current interventions addressing loneliness and its cognitive and behavioral aspects have shown promising results. However, the need for low-threshold interventions such as internet-based solutions might be beneficial due to the associated self-stigmatization of lonely individuals.

This dissertation explores the multifaceted phenomenon of loneliness by examining the cognitive underpinnings and behavioral manifestations. Further, it investigates the potential of an internet-based cognitive behavioral intervention in mitigating feelings of loneliness. Four studies conducted within this dissertation underscore the complexity of loneliness and highlight the potential of internet-based cognitive behavioral interventions to alleviate it. The dissertation discusses an alternative and more flexible theoretical approach by implementing a self-regulatory perspective on adaptive and maladaptive loneliness. Based on the results and the self-regulatory perspective, future directions are formulated concerning potential longitudinal studies, the assessment of loneliness, and interventions.

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1. Introduction

Loneliness, an increasingly recognized public health issue, represents a deeper psychological condition marked by a perceived gap between desired and actual social connections (Peplau & Perlman, 1982). It affects individuals of all ages and backgrounds, manifesting not only in feelings of isolation but also in dissatisfaction with existing social relations (Heinrich & Gullone, 2006). Insofar as loneliness triggers profound emotional distress, fundamentally stemming from an unmet need to belong - a core psychological drive compelling individuals to seek and maintain lasting, significant interpersonal relationships (Baumeister & Leary, 1995).

In recent years, the focus on loneliness has significantly grown, with research demonstrating that prolonged loneliness is associated with negative impacts on mental and physical health as well as increased mortality, among others (see for reviews Hawkley & Capitanio, 2015; Holt-Lunstad et al., 2015; Leigh-Hunt et al., 2017). These findings have emphasized the importance of addressing loneliness as a global health priority (Lim et al., 2023). Furthermore, with restrictions imposed due to the COVID-19 pandemic, loneliness has gained more interest, and studies demonstrated an increase in the prevalence of loneliness compared to pre-pandemic levels, however, with a small effect size (Ernst et al., 2022). Nevertheless, pre-pandemic data has shown that across 113 countries, the prevalence of loneliness ranged from 5.3% to 12.7% across different age groups (Surkalim et al., 2022), underscoring the importance of understanding and addressing loneliness.

Amidst evolving understanding over the last decades, significant efforts have been dedicated to conceptualizing loneliness. These pursuits aimed to decipher the nature of loneliness, exploring its potential dimensions not just as a temporary

emotional state but as a complex, enduring phenomenon that variably affects individuals across different contexts. One of these efforts resulted in the cognitive model of loneliness by Cacioppo and Hawkley (2009), which seeks to explain the cognitive and behavioral mechanisms that perpetuate loneliness. While its plausibility has been recognized in the scientific community, few studies have aimed to systematically evaluate the suggested mechanics, which opens the door for further exploration and validation.

This dissertation seeks to bridge this gap by delving deeper into the phenomenon of loneliness, exploring its cognitive underpinnings and behavioral manifestations, and investigating how interventions might mitigate feelings of loneliness. Overall, this work will address the complexity of loneliness and its associated dynamics by conceptualizing maladaptive loneliness from a self-regulatory perspective.

2. Theoretical background

2.1. Defining loneliness

Loneliness is a subjective feeling rooted in the perceived discrepancy between the desired and actual quality and/or quantity of social relationships (Peplau & Perlman, 1982). Due to the emphasis on its subjective nature, loneliness is differentiated from objective social isolation, which refers to quantifiable deficits in one's social network. Notably, subjective loneliness and objective social isolation show minimal correlation (Coyle & Dugan, 2012). Hence, one may feel intensely lonely despite having a vast social network or not being lonely with few contacts.

Further efforts to conceptualize loneliness have led to the distinction of different types of loneliness. One of these multidimensional approaches was proposed by Weiss (1973), who differentiated between social and emotional loneliness. Social loneliness

refers to the lack of a broader social network of acquaintances, friends, or colleagues, and emotional loneliness stems from the absence of deep, personal relationships, such as those with a spouse or a close friend (Weiss, 1973).

Another approach is to distinguish loneliness by its duration. Young (1982) introduced transient, situational, and chronic loneliness: Transient loneliness refers to short and infrequent periods of loneliness that most individuals experience throughout their lives. Situational loneliness typically emerges following significant life events that disrupt one's social network, such as losing a spouse or transitioning into retirement. However, it is assumed that after a period of psychological distress, situational loneliness diminishes upon adjusting to the new life circumstances/changes in one's social network. Chronic loneliness represents a more persistent condition characterized by ongoing difficulties in forming fulfilling social connections. Unlike situational loneliness, chronic loneliness develops over an extended period and reflects more profound, long-standing interpersonal difficulties (Young, 1982).

While these definitions help outline the complex nature of loneliness, they may not capture its breadth, particularly in understanding how it might affect individuals in a specific sense. This necessitates a deeper exploration into the psychological underpinnings of loneliness, specifically how individual cognitive processes influence and perpetuate these feelings. The subsequent section will address this by exploring a theoretical framework that describes the potential adaptive nature of loneliness and how more prolonged periods might impact cognitive and behavioral aspects.

2.2. The cognitive model of loneliness: adaptive vs. maladaptive loneliness

As outlined above, loneliness arises from an unmet need to belong (Baumeister & Leary, 1995). In this vein, Cacioppo et al. (2006) argued that loneliness might serve as

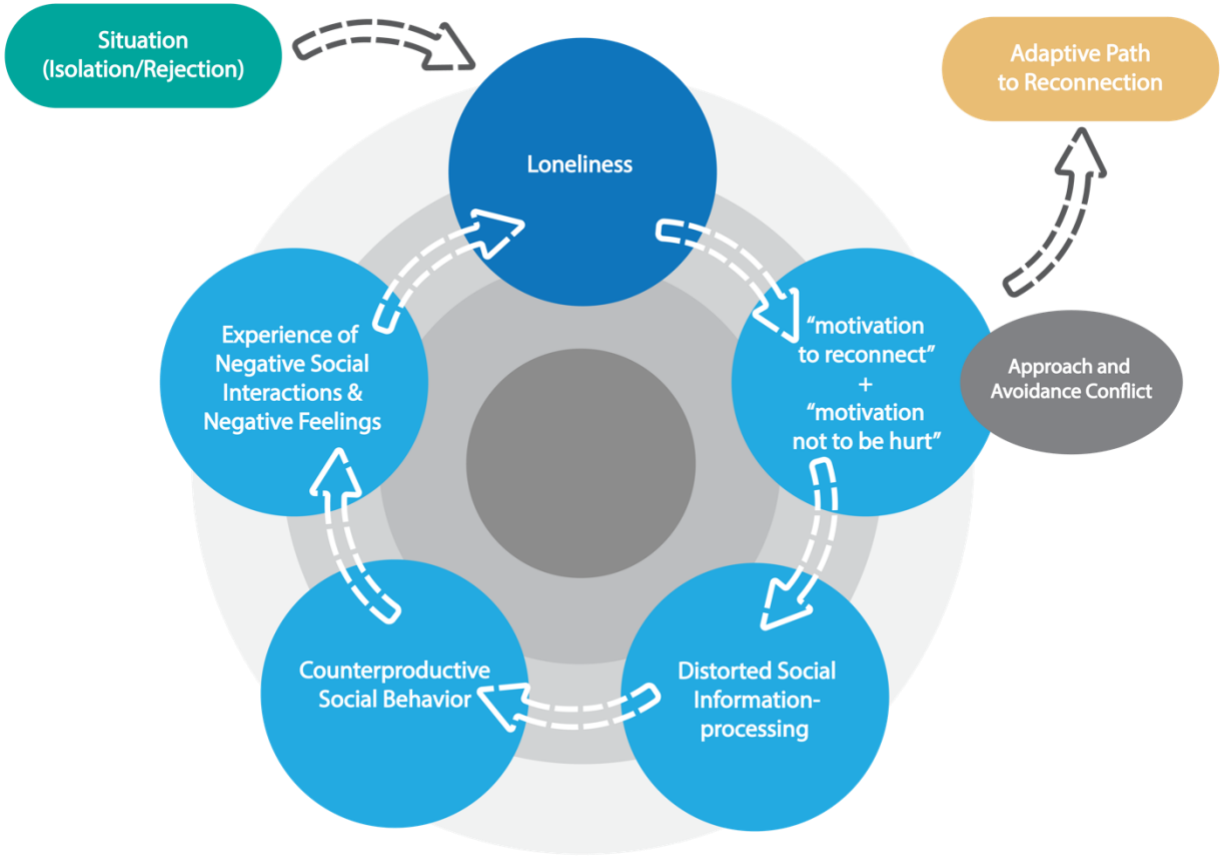
a warning signal for this unmet need and, therefore, encompass an adaptive function. From an evolutionary standpoint, loneliness can be seen as a "social thirst," signaling unmet social needs and promoting adaptive behaviors to strengthen existing relationships or forge new ones (Cacioppo et al., 2014). This suggests that loneliness can serve as a beneficial alarm, prompting necessary adjustments in one's social situations (Cacioppo et al., 2014; Qualter et al., 2015). However, for some individuals, feelings of loneliness may persist over extended periods, and the adaptiveness may vanish instead of leading to reconnection.

One model, in particular, has been the theoretical foundation of numerous studies. Namely, the cognitive model by Cacioppo and Hawkley (2009) which depicts the gradual change of loneliness. It proposes that loneliness can influence human cognition in maladaptive ways (Cacioppo & Hawkley, 2009). The model describes a vicious cycle where feelings of loneliness can lead to an implicit hypervigilance for social threats among lonely individuals. This heightened alertness can result in attentional and memory biases. Lonely individuals are more likely to perceive their social environment as threatening, have pessimistic social expectations, and recall negative events more frequently. Consequently, these negative perceptions increase the likelihood of engaging in behaviors that confirm these biases, further reinforcing negative social interactions and perpetuating feelings of low personal control and social worth (Cacioppo & Hawkley, 2009).

Qualter et al. (2015) expanded the model of Cacioppo and Hawkley (2009) by introducing the reaffiliation motive (RAM) (see Figure 1). They argue that the experiences of social isolation and/or interpersonal rejection lead to a motivational conflict. This simultaneously activates a desire to reconnect with others and a need to

protect oneself from potential social threats in lonely individuals (Cacioppo & Cacioppo, 2018; Qualter et al., 2015). Initially, the activation of the RAM triggers behavioral and cognitive processes that can promote behaviors to reconnect again. One aspect of these processes is hypervigilance, which can be adaptive due to enhanced monitoring for social cues, which can promote behavioral regulations and, therefore, facilitate social reconnection (Qualter et al., 2015). However, for some individuals, this hypervigilance might lead to the self-reinforcing vicious cycle encompassing maladaptive cognitive and behavioral tendencies described in the model of Cacioppo and Hawkley (2009).

Figure 1 Cognitive Model of Loneliness (adapted from Cacioppo and Hawkley (2009) and Qualter et al. (2015); (Krieger et al., 2021))



Note: The yellow box "Adaptive Path to Reconnection" encompasses the behavioral and cognitive processes that promote reconnection triggered by the reaffiliation motive (Qualter et al., 2015), described in detail in the text.

Even though numerous studies used the cognitive model of loneliness as a theoretical foundation when addressing a maladaptive form of loneliness, the terminology and interpretation diverge (see for review: Maes & Vanhalst, 2024). Researchers commonly refer to either “prolonged” or “chronic” loneliness (e.g., Käll, Shafran, et al., 2020). As for how they interpret maladaptive loneliness, some refer to how often feelings of loneliness occur (e.g., Canham et al., 2016), some focus on the distress caused by loneliness (e.g., Beutel et al., 2017), and others on the duration (e.g., Gong & Nikitin, 2021). These discrepancies lead to difficulties in comparing and interpreting findings in terms of how maladaptive loneliness and its consequences manifest. Furthermore, although some findings focus on the adaptive side of loneliness (e.g., Reissmann et al., 2021), they are scarce and underresearched (Maes & Vanhalst, 2024). This hampers a better understanding of the mechanics suggested by the cognitive model of loneliness. Nevertheless, some findings regarding the maladaptive properties of the cognitive model will be presented in the next section.

2.3. Distorted social information processing in lonely individuals

As described in the previous section, the cognitive model of loneliness (Cacioppo & Hawkley, 2009) suggests how longer periods of loneliness may lead to maladaptive cognitive and behavioral dispositions. To investigate this, Spithoven et al. (2017) demonstrated in their review how lonely individuals differ regarding various stages of social information processing. Lonely individuals seem to exhibit more biased interpretations in social situations, anticipate rejection, and evaluate themselves and others more negatively, show higher avoidance tendencies, have heightened social avoidance behaviors, and have fewer social skills, among others (for a detailed review see Spithoven et al., 2017). Recent research supports these findings in terms of more

pronounced negative interpretation biases (e.g., Lau et al., 2021; Nombro et al., 2022; Okruszek et al., 2021), increased rejection sensitivity (e.g., Gao et al., 2017; Zhou et al., 2020), negative self-evaluation and low self-esteem (e.g., Geukens et al., 2022; Ti et al., 2022), more social avoidance behavior (e.g., Skoko et al., 2024), and avoidance motivation (e.g., Saporta et al., 2021) in lonely individuals. These findings collectively provide strong evidence for the relationships between loneliness and the components of the cognitive model of loneliness (Cacioppo & Hawkley, 2009). However, several issues and gaps remain. Most of these findings stem from cross-sectional data, which do not allow any statements regarding causality. Additionally, few studies have investigated multiple components of the cognitive model at once to investigate how they might interact and/or reinforce themselves. Further, most research did not control for psychopathology as a covariate, a factor that may explain certain effects regarding the distorted social information processing. The following section will clarify why this should be considered in loneliness research.

2.4. Distinctiveness of loneliness and its overlap with mental disorders

The associations of loneliness with negative mental and physical health outcomes, as well as increased mortality (e.g., Hawkley & Capitanio, 2015; Holt-Lunstad et al., 2015; Leigh-Hunt et al., 2017), cement the need for loneliness interventions, but they also raise uncertainty. Considering that loneliness has been repeatedly associated with depression and social anxiety (e.g., Beutel et al., 2017; Cacioppo et al., 2010; Lim et al., 2016; Santini et al., 2020), it could be argued that several of the findings described in the previous section (see Spithoven et al., 2017) emerge due to the presence of depressive and social anxiety symptoms in lonely individuals. This notion is further supported by findings that show depression and social

anxiety related to biased information processing (for social anxiety, see Hirsch & Clark, 2004; for depression, see Kube et al., 2020). Although previous research has shown that loneliness is distinct from depression and social anxiety (e.g., Danneel et al., 2020), the potential still exists that comorbid symptoms of depression and/or social anxiety might have confounded said findings regarding the distorted social information processing in lonely individuals.

2.5. Assessing loneliness

Before we look at potential ways to alleviate loneliness, we need to address a further issue regarding loneliness research. Accurately measuring loneliness poses significant challenges due to its subjective nature. Traditionally, the UCLA Loneliness Scale (UCLA-LS; Russell, 1996) has been extensively utilized across studies; however, its predominant focus on the frequency (i.e., by asking how often feelings connected with loneliness occur) may overlook crucial aspects such as intensity and duration, which are equally important to the overall experience of loneliness (Maes et al., 2022; Qualter et al., 2021). Furthermore, discrepancies in prevalence rates of loneliness when using direct (using the word “lonely” in the measure) and indirect (not mentioning the word “lonely” in the measure, such as the UCLA-LS) measurement approaches highlight the complexity of capturing the multifaceted nature of loneliness (Shiovitz-Ezra & Ayalon, 2010). Direct measures, while straightforward, may not capture the full breadth of loneliness, whereas indirect measures might dilute feelings of loneliness with other related feelings. Recent methodological advancements suggest integrating several aspects of loneliness in measures (i.e., frequency, intensity, and duration; Qualter et al., 2021), underscoring a shift towards more nuanced approaches in loneliness research.

2.6. Interventions for loneliness

After delving into how maladaptive loneliness might manifest by introducing the cognitive model of loneliness, demonstrating its current empirical support, and illustrating remaining gaps regarding its mechanisms, the focus will now be on interventions aiming to alleviate maladaptive loneliness that causes distress. The findings of the association between loneliness and poor mental and physical health (e.g., Hawkley & Capitanio, 2015; Holt-Lunstad et al., 2015; Leigh-Hunt et al., 2017) have led to the growing development and evaluation of interventions. While interventions can target individual, community, or societal levels (see for review: Mann et al., 2017; Seewer & Krieger, 2022), the focus will be on the individual level. These interventions focus directly on the individual who, for instance, suffers from feelings of loneliness (Seewer & Krieger, 2022).

2.6.1. Effectiveness

Masi et al. (2011) rigorously assessed the effectiveness of various loneliness interventions in their meta-analysis by categorizing them into four groups: enhancing social skills, boosting social support, fostering social interaction opportunities, and targeting maladaptive social cognitions through methods like cognitive behavioral therapy (CBT). CBT showed the most significant impact, with a moderate effect size (d = 0.60), supporting the cognitive model's focus on changing social cognitions to reduce loneliness. Similarly, Zagic et al. (2022) found that improving skills to manage maladaptive attributional biases, fear-related avoidance of social situations, and barriers to social contact was the most effective strategy for addressing deficits in the perceived quality of social connections (g = − 0.53). Although these findings are promising, they were based on just four (Masi et al., 2011) and five (Zagic et al., 2022)

randomized controlled trials (RCTs). Furthermore, Hickin et al. (2021) analyzed psychological interventions and found that they were generally effective with a small effect size (g = 0.43). Whether these interventions were CBT-based did not significantly alter outcomes (Hickin et al., 2021). Despite promising results, existing studies often suffer from methodological limitations such as small sample sizes or lack of control conditions, highlighting the need for more rigorous RCTs to confirm these findings.

2.6.2. Internet-based interventions

The advent of technology and the internet has facilitated the development of ways to provide novel and accessible approaches to addressing mental health. In particular, the increase in the development of Internet-based cognitive behavioral interventions (ICBT) (Andersson, 2018) provides a promising opportunity to effectively address maladaptive loneliness. Seewer, Skoko, and Krieger (2022) argue for the potential of ICBT interventions for loneliness by emphasizing their flexibility regarding when and where individuals might access them, their easy scalability, and the greater extent of anonymity and privacy they provide. These last two points can be especially beneficial when targeting lonely individuals due to the perceived self-stigma regarding feelings of loneliness (Barreto et al., 2022; Kerr & Stanley, 2021; Lau & Gruen, 1992) and due to the previously introduced social avoidance behavior tendency (Skoko et al., 2024; Spithoven et al., 2017).

Recent advancements in digital health have led to the development and evaluation of Internet-based interventions for loneliness with encouraging results. A pilot RCT revealed that participants undergoing guided (i.e., weekly feedback by a therapist or coach) ICBT experienced a more significant reduction in loneliness than those in a waitlist-control group (WL) (Käll, Jägholm, et al., 2020) with the effects

persisting two years post-treatment (Käll, Backlund, et al., 2020). Further research involving a three-arm RCT compared guided ICBT with an Internet-based Interpersonal Therapy (IIPT) and a WL group (Käll et al., 2021). The study found that reductions in loneliness were significantly greater in the ICBT group than in both the IIPT and waitlist-control groups. Notably, there was no significant difference in loneliness reduction between the IIPT and WL groups (Käll et al., 2021). These findings underscore the effectiveness of ICBT in mitigating loneliness.

The fourth study of this dissertation aimed to first replicate the findings of Käll, Jägholm, et al. (2020) by evaluating an adapted German version of the intervention and second to expand those results on the role of human contact provided through weekly guidance. This three-arm RCT examined and evaluated the efficacy of the SOLUS-D intervention, an ICBT intervention aimed at reducing loneliness, with three conditions (i.e., guidance, automated messages, and WL) (see the study protocol for e detailed description of SOLUS-D Seewer, Skoko, Käll, et al., 2022). In comparison to the version of Käll, Jägholm, et al. (2020), SOLUS-D was enriched and extended with elements of mindfulness, self-compassion, acceptance and commitment, and social skills. While investigating a potential low-threshold intervention to reduce loneliness was the primary aim, it was also investigated if SOLUS-D would reduce cognitive and behavioral components of the cognitive model of loneliness (Cacioppo & Hawkley, 2009).

3. Main findings of the studies

The following section summarizes the results of the studies included in this dissertation. All study samples were German-speaking and from the public. Studies I and III stem from the same sample, and Study II stems from another, but neither

sample included inclusion criteria regarding loneliness levels. Study IV contains a sample that suffered from loneliness.

3.1. Study I

Revisiting the Cognitive and Behavioral Aspects of Loneliness: Insights from Different Measurement Approaches

Journal: Journal of Psychopathology and Behavioral Assessment, 2024 [submitted]

Authors: Andrej Skoko, Noëmi Seewer, Marcus Mund, Tobias Krieger

This study delves into the maladaptive cognitive and behavioral components of loneliness while employing various measurement approaches to assess loneliness. The study utilizes a comprehensive cross-sectional analysis of 790 German-speaking adults, first comparing different measures for categorizing the sample into lonely and non-lonely: frequency, distress, and chronicity. Second, we performed ANCOVAs to investigate group differences (lonely vs. non-lonely) regarding components of the cognitive model of loneliness for each method of distribution (frequency, distress, and chronicity) while controlling for depressive and social anxiety symptoms.

Key Findings:

- Different methods of assessing loneliness (frequency, distress, chronicity) reveal varied prevalence rates, and while the degree of agreement was mostly moderate, the three measures seem to assess unique aspects of loneliness.
- Significant group differences (lonely vs. non-lonely) were found regarding all cognitive-behavioral constructs linked to the cognitive model of loneliness, no matter which of the three methods of distribution (frequency, distress, chronicity) was used. These constructs include interpretation bias in socially

ambiguous situations, rejection sensitivity, social avoidance behaviors, distress disclosure, self-esteem, and avoidance goal motivation.

This study emphasizes the challenges and importance of choosing appropriate tools to capture the multifaceted nature of loneliness. It supports the cognitive model of loneliness by showing that different dimensions of loneliness are linked with specific maladaptive cognitive and behavioral patterns, even when controlling for psychopathology.

3.2. Study II:

Preliminary Investigation of the Regulatory Loop of Loneliness and the Protective Role of Self-Esteem – A Cross-Sectional Study

Journal: Current Psychology, 2024

Authors: Andrej Skoko, Janko Kaeser, Noëmi Seewer, Tobias Krieger

This study explores the relationships within the cognitive model of loneliness proposed by Cacioppo and Hawkley (2009) in a cross-sectional design, particularly focusing on how self-esteem may mitigate loneliness's adverse effects. A community sample of 436 German-speaking adults was recruited to implement conditional process analyses in order to assess the associations between loneliness, interpretation bias in social situations, social avoidance behavior, and self-esteem while controlling for relevant covariates such as psychopathology.

Key findings:

- Loneliness positively correlates with interpretation bias and social avoidance and negatively with self-esteem.

- The three mediation models mimicking the cognitive model of loneliness showed strong, significant indirect effects pointing towards a significant link between loneliness, interpretation bias, and social avoidance behavior.
- Self-esteem significantly moderated these effects, with higher levels dampening the negative impact of loneliness on interpretation bias.

The results cautiously point towards a cyclic relationship as suggested by the cognitive model of loneliness (Cacioppo & Hawkley, 2009), underscoring the importance of addressing maladaptive social cognitions and behaviors in interventions aimed at reducing loneliness and highlighting self-esteem as a potential protective factor that could mitigate the cyclical nature of loneliness.

3.3. Study III

Untangling the Web of Prolonged Loneliness: A Longitudinal Examination of the Cognitive Model of Loneliness

Journal: Journal of Personality, 2024 [under review]

Authors: Andrej Skoko, Marcus Mund, Noëmi Seewer, Tobias Krieger

This longitudinal study investigates the interplay between loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior over six months in order to explore the dynamics suggested by the cognitive model of loneliness (Cacioppo & Hawkley, 2009). The study involved 785 German-speaking adults, assessed at three time points using a Cross-Lagged Panel Model (CLPM; between-person) and a Random Intercept Cross-Lagged Panel Model (RI-CLPM; within-person).

Key Findings:

- The CLPM showed that initial levels of loneliness predict increases in social avoidance behavior, and more negative interpretation biases lead to increased loneliness and social avoidance over time.
- The RI-CLPM revealed that higher-than-usual levels of loneliness are associated with lower-than-usual interpretation biases and vice versa. Further, higher-than-usual levels of loneliness are associated with higher-than-usual social avoidance behavior and vice versa.

Both models highlight the nuanced interplay between cognitive and behavioral components, suggesting a complex relationship rather than a straightforward cyclic exacerbation. While the study supports parts of the cognitive model, it also indicates the need for broader approaches to understanding and addressing prolonged loneliness.

3.4 Study IV

Efficacy of an Internet-based self-help intervention with human guidance or automated messages to alleviate loneliness: A three-armed randomized controlled trial

Journal: Scientific Reports, 2024

Authors: Noëmi Seewer, Andrej Skoko, Anton Käll, Gerhard Andersson, Maike Luhmann, Thomas Berger, Tobias Krieger

This randomized controlled trial assesses the efficacy of an internet-based cognitive behavioral therapy (ICBT) aimed at reducing loneliness by comparing two versions of the intervention—one with human guidance and another with automated messages—against a WL group with 243 adults suffering from loneliness recruited.

Key Findings:

- At post-assessment, both intervention groups showed significantly lower loneliness levels than the WL group, with the human-guided intervention proving more effective than the automated messages.
- The pooled intervention groups demonstrated significantly lower levels of depressive symptoms, social anxiety, social avoidance behavior, and rejection sensitivity at post-assessment compared to the WL group.

The study underscores the potential of ICBT, particularly with human guidance, as a viable and effective method for reducing loneliness and associated psychopathological symptoms.

4. Discussion

In the following, I will build upon the results of the four studies and reflect on how they support the cognitive model of loneliness (Cacioppo & Hawkley, 2009) and previous related findings and how some aspects might need to be rethought regarding the model. Further, I will introduce an alternative framework to interpret the complex dynamics of loneliness. Finally, some general limitations and future directions are formulated.

4.1. Further support for the cognitive model of loneliness

Inspecting the different components of the cognitive model of loneliness (Cacioppo & Hawkley, 2009), we found cross-sectional support for the relationships between loneliness and various cognitive and behavioral components associated with the model (Study I-III). Our analyses reaffirm that loneliness correlates significantly with maladaptive social cognition and behavioral tendencies. Study I, in particular, further strengthens the findings presented in the review by Spithoven et al. (2017) showing significant differences between lonely and non-lonely individuals separated through

three different facets of loneliness - frequency, distress, and duration - regarding cognitive and behavioral components (i.e., interpretation bias, rejection sensitivity, social avoidance behavior, distress disclosure, self-esteem, and avoidance goal intensity). These results held up while controlling for depressive and social anxiety symptoms, which have been seldom implemented in past research (Spithoven et al., 2017).

Study II expands on these findings and further provides preliminary support for the cognitive model of loneliness by incorporating loneliness, interpretation bias, and social avoidance behavior into three mediation models mimicking the cognitive model. All pathways of the three simple mediation models were significantly positive even when controlling for a variety of covariates, including depressive and social anxiety symptoms. Hence, the components seem to reinforce each other, potentially leading to the self-reinforcing vicious cycle described by Cacioppo and Hawkley (2009). This is the first study to examine these dynamics of loneliness and multiple associated. However, the study's cross-sectional design prevents a causal interpretation of the current results.

The results of Study III, however, stem from longitudinal data and yielded more complex and not straightforward pathways, as suggested by the reinforcing nature of the cognitive model of loneliness (Cacioppo & Hawkley, 2009), which will be discussed in the next section. Nevertheless, one finding consistent with the model is the positive reciprocal cross-lagged effect of loneliness and social avoidance behavior in the RI-CLPM (within-person effect). This suggests that higher-than-usual levels of loneliness predict heightened tendencies for social avoidance behavior than normal, and more social avoidance behavior subsequently reinforces and exacerbates loneliness.

In sum, the results of Study I-III collectively provide further support for the cognitive model of loneliness (Cacioppo & Hawkley, 2009). Primarily, the cross-sectional studies (Study I and II) are not only in line with previous findings (Spithoven et al., 2017) but also expand them by at least incorporating depressive and social anxiety symptoms as covariates, which shows that the relationship between loneliness and the cognitive and behavioral components is not explained by psychopathology. This converging evidence seems to underscore the robustness of the cognitive model as a framework for understanding the interplays between loneliness and its components, yet, as already indicated, the longitudinal data point towards a more complex interplay.

4.2. Complex longitudinal dynamics of loneliness

In exploring the intricate longitudinal dynamics of loneliness, Study III reveals the nuanced interrelations that challenge straightforward interpretations of the cognitive model of loneliness. While some findings align neatly with expected patterns - such as the within-person cross-lagged effects between loneliness and social avoidance behaviors - other results suggest more complex interplays that merit deeper scrutiny.

The results of the CLPM (between-person effects) in Study III demonstrate that the expected reciprocal relationships between loneliness, interpretation bias, and social avoidance behavior were not fully supported, challenging the notion of a self-reinforcing cycle posited by the cognitive model of loneliness (Cacioppo & Hawkley, 2009). While interpretation bias predicted subsequent increases in loneliness and social avoidance, loneliness directly predicted social avoidance but not interpretation bias. Specifically, the pathway from interpretation bias to increased loneliness reinforces the model's view that negative social cognitions can escalate feelings of

loneliness (Cacioppo & Hawkley, 2009). Similar findings support this (e.g., Okruszek et al., 2021) but contradict those from Lau et al. (2021), where loneliness seems to be the driving force for cognitive biases. Additionally, the link between loneliness and maladaptive social behavior aligns with past research (Nurmi & Salmela-Aro, 1997; Preece et al., 2021), highlighting that loneliness can trigger maladaptive behaviors such as withdrawal from social interactions. However, these behaviors did not intensify loneliness over time, indicating that while they may be a response to loneliness, they do not necessarily perpetuate it. Instead, they may maintain loneliness by limiting opportunities for positive social interactions.

The negative bidirectional cross-lagged effect between loneliness and interpretation bias in the RI-CLPM (within-person effect) does not replicate the suggested pathways of the cognitive model of loneliness (Cacioppo & Hawkley, 2009). However, they might hint at the adaptive nature of loneliness. The findings that higher-than-usual loneliness predicted lower-than-usual interpretation bias might point towards the activation of the reaffiliation motive, driving adjustments in cognitive biases to foster social connections (Qualter et al., 2015). This could manifest as reduced interpretation biases when individuals experience elevated loneliness as a strategy to reduce the fear of rejection and enhance social re-engagement. Conversely, elevated interpretation bias reducing loneliness may reflect heightened social vigilance. Although negatively skewed, this hypervigilance and the heightened attention towards social cues could inadvertently heighten awareness of social opportunities, addressing social needs more effectively. These unexpected pathways highlight the complexity of loneliness dynamics and the need for further studies using methodologies like experience sampling to clarify these mechanisms.

In sum, the longitudinal dynamics of loneliness investigated in Study III point towards intertwined relationships between loneliness, interpretation bias, and social avoidance behavior that are not as straightforward as the cognitive model of loneliness (Cacioppo & Hawkley, 2009) suggests. Further studies need to confirm our findings and, for instance, incorporate different aspects of the components (i.e., social skills, rejection sensitivity, etc.) depicted in the model and/or use different methods to validate its suggested pathways.

4.3. Disrupting the maladaptive cycle of loneliness

Previous findings (Masi et al., 2011; Spithoven et al., 2017) and Study I-III highlight the necessity of targeting maladaptive social cognitions and behaviors to interrupt the vicious cycle of loneliness effectively. This approach is substantiated by the results of an ICBT intervention (SOLUS-D), detailed in Study IV, which was structured to address and mitigate the elements sustaining this cycle directly suggested in the cognitive model of loneliness (Cacioppo & Hawkley, 2009). Results demonstrated significant reductions in loneliness across the intervention groups compared to the control condition, with significantly lower loneliness levels at post-assessment in the human-guided condition compared to the automated message condition. This suggests that human interaction may play a crucial role in enhancing the effectiveness of interventions aimed at reducing loneliness.

Moreover, the intervention led to notable improvements in depressive and social anxiety symptoms. This stands in line with previous trials that have shown reductions in depressive (Käll et al., 2021) and social anxiety symptoms (Käll, Jägholm, et al., 2020). This suggests that even though loneliness and related psychopathological symptoms such as depression and social anxiety have been shown to be distinct from each other

(e.g., Danneel et al., 2020), there either seem to be certain underlying themes between them that overlap, which were addressed by the intervention or the reduction of loneliness led to decrease in symptoms or vice versa. Both seem possible due to the continued association between loneliness and depressive and social anxiety symptoms (e.g., Beutel et al., 2017; Cacioppo et al., 2010; Lim et al., 2016; Santini et al., 2020). However, further research is needed to clarify the dynamics between loneliness and psychopathology and adequately design interventions to address maladaptive loneliness with comorbid mental health issues such as depression and social anxiety.

As for the secondary outcomes associated with the cognitive model of loneliness (Cacioppo & Hawkley, 2009), the intervention groups demonstrated reduced social avoidance behavior and rejection sensitivity compared to the WL group. As for the reduction in social avoidance behavior, the results of Study III also suggest that lower-than-usual social avoidance behavior could lead to lower-than-usual levels of loneliness. Additionally, previous findings where ICBT interventions were implemented in the context of social anxiety led to decreases in social avoidance (e.g., Hedman et al., 2011). Further, as already mentioned, SOLUS-D contains elements of mindfulness, which has been shown to be a protective factor against rejection sensitivity (e.g., Peters et al., 2016). However, for other secondary outcomes like interpretation bias linked to the cognitive model of loneliness, no significant differences between the intervention conditions and the control group emerged. Contrary to these results, a recent study showed that loneliness may be reduced through cognitive bias modification training, where the mechanism of action is interpretation bias (Riddleston et al., 2023). On a different note, the negative bidirectional cross-lagged within-person effects between

loneliness and interpretation bias of Study III imply that it might not be necessary for biased cognition to decrease to alleviate feelings of loneliness. In general, it may be possible that due to the complexity of loneliness, which can stem from varied causes (Rokach, 1997), changes at the individual level might not always be apparent at the group level. This implies that tailoring interventions to address the specific causes and circumstances of loneliness could better disrupt its vicious cycle (Käll, Shafran, et al., 2020), as individuals may require different strategies based on their unique social situations and underlying reasons for loneliness.

In sum, the results of Study IV first support the findings of Studies I-III by pointing towards the interconnectedness of loneliness and associated cognitive and behavioral aspects, second demonstrate that ICBT interventions effectively reduce loneliness, and finally indicate that ICBT interventions addressing loneliness might additionally contribute to boosting mental health by alleviating depressive and social anxiety symptoms.

4.4. Limits of the cognitive model to describe (mal)adaptive loneliness

While the cognitive model of loneliness (Cacioppo & Hawkley, 2009) provides a comprehensible framework for describing the interplay between loneliness, social cognition, and behavior, the results of the studies suggest that certain aspects of the model exhibit limitations that may restrict its applicability to understanding and addressing the complexities of loneliness fully.

A significant limitation of the cognitive model is its lack of clarity in distinguishing between adaptive and maladaptive loneliness and identifying the specific triggers, conditions, or duration under which this transition occurs. Our longitudinal study (Study III) reveals complex interrelations and dynamics that challenge straightforward

interpretations suggested by the model. The findings indicate nuanced interactions between loneliness, interpretation bias, and social avoidance behavior, which do not always align with the expected cyclic exacerbations posited by the model. This ambiguity makes it difficult to pinpoint when and how loneliness transitions from being a potentially adaptive motivating force to a maladaptive, self-perpetuating malaise that exacerbates distress and may lead to adverse (mental) health outcomes.

The model often implies a linear, deterministic process whereby loneliness leads to heightened social vigilance and subsequent maladaptive social cognitions and behaviors. This deterministic view may not fully encapsulate the varied ways individuals react to and cope with loneliness. For instance, findings from the RI-CLPM (Study III) suggested that higher-than-usual levels of loneliness could lead to decreased interpretation biases, possibly as a temporary adaptive mechanism to foster social re-engagement. This contradicts the model's suggestion of an inevitable progression towards maladaptive outcomes and highlights the potential for individuals to employ adaptive strategies that the model does not currently predict.

In sum, while the cognitive model of loneliness is a powerful tool for understanding certain aspects of loneliness, these limitations highlight the need for more nuanced and flexible frameworks. Such frameworks should better distinguish between adaptive and maladaptive loneliness, accommodate the variability of individual experiences, and offer more dynamic pathways that consider the potential for both positive and negative outcomes.

4.5. Alternative approach to (mal)adaptive loneliness

To potentially address these shortcomings of the cognitive model of loneliness (Cacioppo & Hawkley, 2009), the subsequent section will explore an alternative view on

understanding (mal)adaptive loneliness by incorporating the concept of self-regulation, which has been thoroughly explored in the psychotherapeutic context.

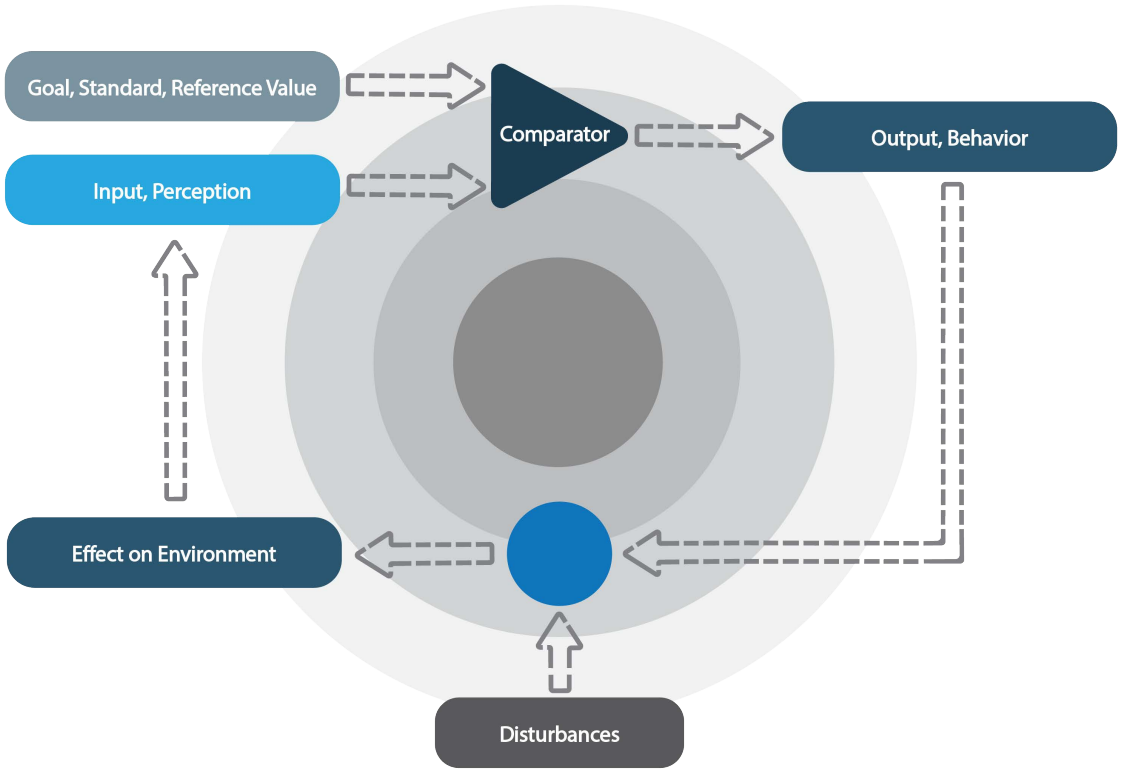
4.5.1. Loop of self-regulation

Since the term self-regulation is defined variously in the literature, I will rely on the definition by Caspar (2016), which understands self-regulation as the entirety of what a person does, consciously or unconsciously, to achieve a good match between their perception of the current situation and their goals. These goals may include needs, personal values, short-term objectives, or social and cultural norms. Thus, taking action results from the discrepancy between the actual state and the desired goals and/or norms.

Carver and Scheier (1998) proposed a model describing a “loop” of self-regulation (see Figure 2), which was built around the TOTE model (Test-Operate-Test-Exit) by Miller et al. (1960). According to the TOTE model, a person continually tests whether a specific goal has been achieved. If not, actions are (re)performed to achieve the goal. Similarly, the loop of self-regulation involves a "reference" value and a "sensed" (or perceived) value facing each other. The reference value may include goals, motives, standards, or cultural norms. The sensed value (input) comprises perceived contents. In a hypothetical construct, often called a "comparator," both values are compared. If there is a match between the sensed and reference content, no action is initiated, and the regulation process is exited. If the reference value is not met, ideally, an action (i.e., behavior) is performed to bring the sensed value closer to the reference value. The behavior of other people and the environment or context also play a role. These external factors can either facilitate or hinder successful self-regulation. The interplay of one's actions and the environment results in a (possibly new) perceived

input, which is again compared with the reference value in the comparator. If the comparator indicates a match, subsequent cycles in the loop attempt to maintain this state; if there is a mismatch, old behavior is continued, or new behavior is tried to achieve a match (Carver & Scheier, 1998; Caspar, 2016). A helpful metaphor for understanding the loop of self-regulation is to imagine a thermostat that reacts to the discrepancy between the actual and desired temperature (for a detailed description of this metaphor, see Carver & Scheier, 1998).

Figure 2: Loop of self-regulation (Carver & Scheier, 1998)



4.5.2. Self-organization

Before delving into how the loop of self-regulation can help better understand behaviors, it is also necessary to clarify the difference between "deliberate" and "self-organized" processes and their interplay. Deliberate processes (e.g., behaviors) occur serially and require more resources (Carver & Scheier, 2002). In contrast, self-organized

processes do not proceed consciously and thus require fewer resources. In the self-regulation process, each element (reference value, perception, comparator, behavior) can arise either deliberately or self-organized. Both processes have advantages and disadvantages and, ideally, complement each other well (Carver & Scheier, 1998; Caspar, 2016). However, multiple and competing discrepancies detected by the comparator can lead to higher tension (i.e., distress). This may result in potential behaviors that might initially be adaptive in certain instances but could lead to overall self-organized behavioral patterns that become maladaptive to seek a lower-tension state (referred to as "local minimum" by Caspar, 2016). These states are stable patterns of cognition, emotions, behaviors, and environmental factors that, despite relative stability, can involve significant discomfort due to internal conflicts (or higher baseline tension). It is argued that leaving such a local minimum (i.e., maladaptive loneliness) requires generating and exposure to more tension (i.e., addressing maladaptive cognitions and behaviors connected to loneliness) in order to lessen baseline tension, underscoring the complexity of change (Caspar, 2016; Caspar et al., 1992).

4.5.3. Perceived control of incongruence

Another way to refer to the discrepancy between sensed or actual state and desired reference is "incongruence" (Grawe, 1998, 2004). One aspect determining the amount of distress connected to incongruence is the perceived control over it (Caspar, 2016). Controllable incongruence drives adaptive behavioral adjustments over the long term and enhances self-regulation capacity. Thus, incongruence is not inherently detrimental but can lead to new experiences of competence. However, persistent and uncontrollable incongruence can initiate maladaptive self-organized processes that become functionally autonomous, no longer serving specific goals like achieving social

connectedness. In this vein, loneliness, an inherently unpleasant experience, is influenced significantly by a lack of perceived control over social interactions and the quality of relationships (Luhmann & Hawkley, 2016). Adaptive loneliness, therefore, can be seen as controllable incongruence, where adjustments are feasible in the short to medium term. Maladaptive (and often prolonged) loneliness involves perceived uncontrollability, which complicates and potentially prolongs the experience of loneliness (Skoko & Krieger, in press).

4.5.4. Loops of loneliness

Adapting both the definition of loneliness by Peplau and Perlman (1982) and the evolutionary perspective of Cacioppo et al. (2014) into this self-regulatory framework, loneliness involves a discrepancy between the desired (reference) and current (sensed) state, which, if adaptive, prompts efforts to expand social networks or deepen existing connections, thereby reducing feelings of loneliness (Skoko & Krieger, in press). The effectiveness of such behaviors in reducing incongruence depends on various factors. The self-regulation loop that governs this process can be disrupted inside its components - perception, reference value, comparator, behavior, or environment - by various sources identified in empirical studies (Spithoven et al., 2017). These disruptors prevent the alignment between desired and current states, leading to the persistence or emergence of loneliness. Over time, loneliness can lose its adaptive function as self-organization processes solidify a functionally autonomous state (Skoko & Krieger, in press). Understanding this can help tackle these distortions and disrupt maladaptive self-organized processes in individuals who suffer from loneliness. The following section will provide examples of disruptions inside some of the components of the loop of self-regulation in the context of previous findings and the ones presented in this

dissertation. Further, the potential of how the loop of self-regulation might explain the dynamic between adaptive and maladaptive loneliness will be discussed.

As for the initial perception process to generate the sensed value, the potential disruptions have already been discussed, showing that lonely individuals tend to exhibit distorted social information processing (Spithoven et al., 2017). These disruptions at the beginning of the loop, such as faster attentional focus toward potential social threads (e.g., Bangee & Qualter, 2018), increased rejection sensitivity (Study I), and more prominent interpretation bias (Study I and II) in lonely individuals, might hinder adaptive and deliberate self-regulation processes and promote self-organized maladaptive behaviors, such as avoiding potential threats and thus prevent from potentially positive experiences in social interactions. Similarly, the between-person cross-lagged effects of Study III showed interpretation bias to be the driving force for loneliness and social avoidance behavior.

The reference value, which includes goals, motives, norms, or standards, guides the behavior to align the sensed current state with the desired outcome. In the case of loneliness, the reference value could be, for instance, the satisfaction with the amount of relationship. However, while the reference can be similarly formulated for several individuals, the specific value can vary, aligning with loneliness's subjective nature (Skoko & Krieger, in press). Not only can this apply to the quantity but also the quality of relationships. Therefore, depending on the prioritization of certain types of relationships, the reference value may be more oriented towards intimate bonds rather than social inclusion. Along these lines, feelings of a certain type of loneliness (i.e., social and emotional) may only subside when the specific unmet need is addressed (Weiss, 1973). This notion is supported by findings indicating that attachment predicts

emotional loneliness and social integration predicts social loneliness (DiTommaso & Spinner, 1997).

The comparator serves as a simple function to assess incongruence between the sensed and reference values. Its activation, which can be either self-organized or deliberate, varies in frequency, duration, and accuracy, affecting how one deals with incongruences (Caspar, 2016). One aspect of this activation is that it generally triggers negative emotions (i.e., loneliness), which can vary in intensity depending on which discrepancy is detected. It is argued that there is a tendency for intense emotions to promote more maladaptive self-organized behavior (Caspar, 2016; Gross, 2015).

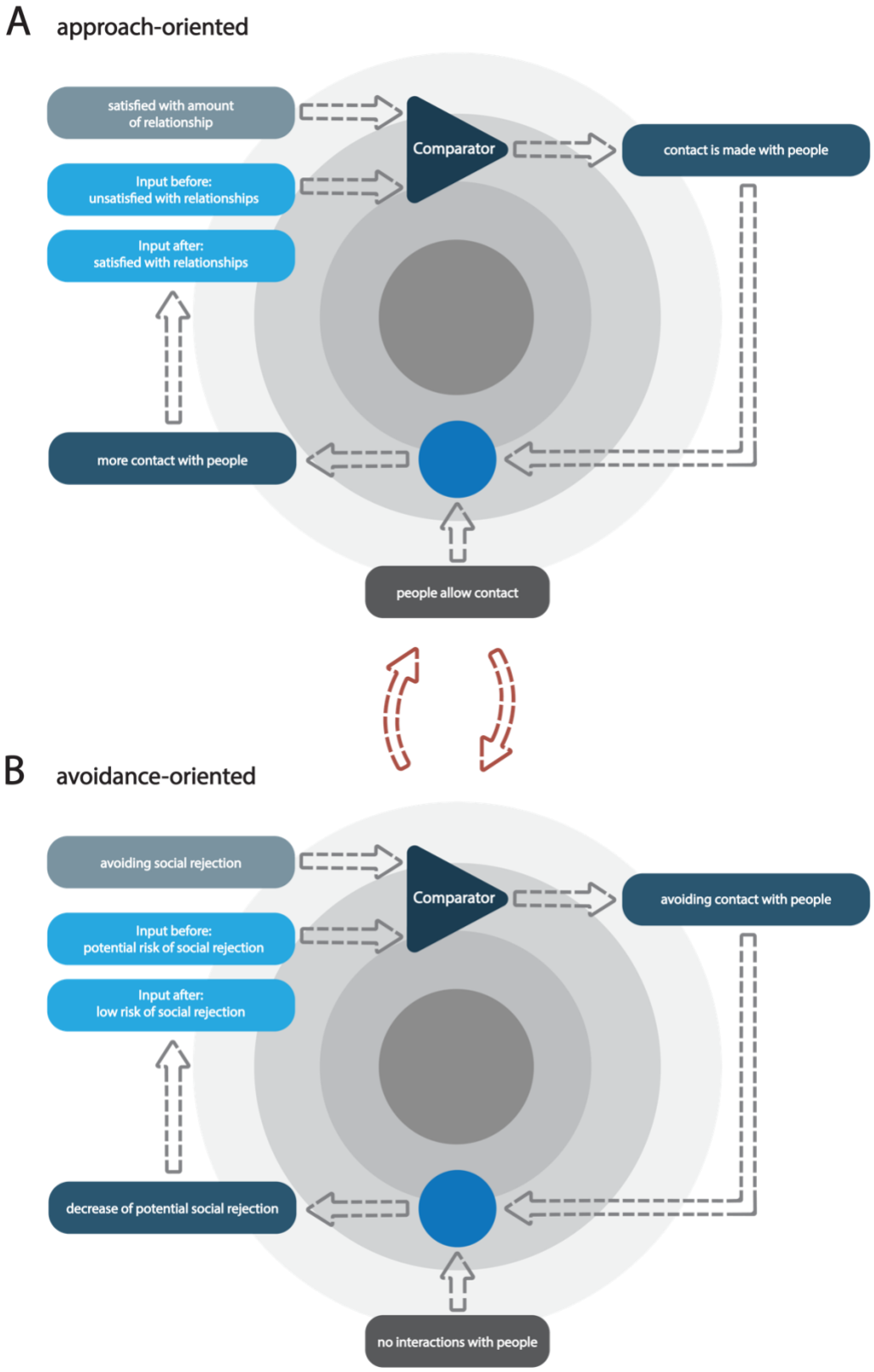
In the case of loneliness, it is argued that two loops might run concurrently - one addressing social needs (activation of comparator triggering loneliness; see Figure 3A) and another protecting against potential threats like social rejection (activation of comparator triggering fear; see Figure 3B) (Skoko & Krieger, in press). Through repeated experiences of social rejection, the comparator of the avoidance-oriented loop might activate more frequently compared to the approach-oriented one, which might lead to hypervigilance for potential social threads and to the prioritization of avoiding social situations (similar to the model of Cacioppo & Hawkley, 2009). In accordance with this, avoidance motivation in lonely individuals has been found in previous findings (see Spithoven et al., 2017) and Study I. Therefore, in the case of maladaptive loneliness, the avoidance-oriented loop might assert itself over the approach-oriented one, which can lead to maladaptive self-organized behavior.

Regarding such behaviors, it has been postulated that they display suboptimal or even counterproductive behaviors that, in turn, elicit negative reactions from others, thus confirming their initial concerns regarding the contents of avoidance goals in the

sense of a self-fulfilling prophecy (Cacioppo & Hawkley, 2009). Two variants of maladaptive and counterproductive behaviors are suspected: on the one hand, the attempt to make contact with inappropriate behavior, and on the other hand, the omission of social behavior (Spithoven et al., 2017). In this regard, the study by Preece et al. (2021) showed that lonely individuals tend to use behavioral strategies such as suppression of emotional expression, active rejection, or social withdrawal. Study I-III confirm the second variant tendency concerning social avoidance behavior in lonely individuals. Such maladaptive behavior is argued to be mostly self-organized and requires fewer cognitive resources (Caspar, 2016). However, these potentially old self-organized behaviors may help reduce current tension (i.e., through avoidance rejection) but can cause significant distress (i.e., loneliness) in individuals if the comparator remains constantly activated due to a perceived incongruence (i.e., lack of meaningful relationships). These rigid self-organized behaviors cannot be easily replaced by more adaptive behaviors.

Figure 3: Exemplary depiction of two loops of self-regulation connected to loneliness

(adapted from Skoko & Krieger, in press)



Note: The red arrows indicate that both loops can affect and/or hinder each other. For instance, reducing fear of rejection (B: avoidance-oriented) can hinder the reduction of loneliness (A: approach-oriented).

4.5.5. Understanding (mal)adaptive loneliness through the self-regulatory lense

The previous section established how loneliness and its cognitive and behavioral underpinnings discussed throughout this dissertation might be interpreted through the loop of self-regulation and how two loops might explain the cooccurrence of adaptive and maladaptive tendencies (Skoko & Krieger, in press). As suggested, the cognitive model of loneliness (Cacioppo & Hawkley, 2009) has shortcomings regarding its deterministic tendencies regarding the mutual exacerbation of its components over time and the inability to capture the subjective nature of loneliness. It fails to explain the transition or cooccurrence of adaptive and maladaptive loneliness. As demonstrated in the previous section, the loop of self-regulation (Caspar, 2016) might provide a more nuanced theoretical framework while integrating critical aspects of the cognitive model of loneliness.

Suggesting two loops of self-regulation (an approach-oriented vs. an avoidance-oriented), where efforts to alleviate the corresponding incongruence might affect and/or hinder each other, may be more feasible to describe (mal)adaptive loneliness. Instead of implying that loneliness can either be adaptive or maladaptive, loneliness may trigger a motivational conflict between seeking affection and avoiding rejection (similar to the notion of Qualter et al., 2015), which could lead to both adaptive and maladaptive tendencies. Previous findings support this notion by showing that loneliness can lead to both increases and decreases in subsequent social interaction (Reissmann et al., 2021). Thus, to distinguish between adaptive and maladaptive loneliness, the strength of desire to resolve the incongruence of one loop over another must be considered. For instance, if the desire to protect oneself from social rejection is greater than the need for satisfying social relationships, loneliness might be

maladaptive, and biased cognitions and self-organized avoidance behavior could be more prominent. However, this should not imply a dichotomous view between adaptive and maladaptive loneliness but more of a continuous one, where, for example, deliberate adaptive behaviors can manifest (seeking social relationships) while simultaneously incongruence regarding the fear of rejection is experienced.

In the case of the repeatedly mentioned bidirectional within-person cross-lagged effects of Study III, increases in loneliness above the usual level seem to trigger more-than-usual social avoidance behavior. This could be caused by the anticipation of engaging in social situations, which triggers the comparator of the avoidance-oriented loop that leads to elevated fears. Consequently, the fear of rejection might be more prominent than feelings of loneliness, and the resulting maladaptive self-organized behavior is social avoidance. The reverse cross-lagged effects also seem plausible since more-than-usual social avoidance behavior hinders the approach-oriented loop, which results in more-than-usual levels of loneliness.

Simultaneously, as previously discussed, the negative within-person effects of loneliness and interpretation bias might hint toward adaptive mechanisms (similar to the RAM: Qualter et al., 2015). Higher-than-usual loneliness might lead to adjustments in the perception of the input (perceived value). This adjustment might affect both loops: less interpretation bias firstly regarding existing social relationships and/or oneself might reduce the perceived incongruence in the first approach-oriented loop (see Figure 3A) and secondly regarding others where they might be perceived as less threatful (see Figure 3B). Finally, the initial higher-than-usual interpretation bias might also lead to adjustments in the reference value. Due to potentially more hostile interpretations of others, one might increase their focus on the quality of relationships

rather than the quantity since more social interaction could increase the potential for social rejection. However, these assumptions should be taken with a grain of salt since more research is needed to validate these pathways. Additionally, it can be argued that the last scenario still might be more maladaptive than adaptive since it could reinforce the fear of rejection even more.

Taken together, the cognitive model of loneliness (Cacioppo & Hawkley, 2009) might be more straightforward regarding its understandability. However, the loop of self-regulation provides a more nuanced point of view regarding individual dynamics of loneliness and a potential way to explain adaptive and maladaptive tendencies better. In other words, it might be more flexible in explaining the unique dynamics of lonely individuals, where the cognitive model of loneliness (Cacioppo & Hawkley, 2009) fails to account for this individuality. Still, several assumptions of the cognitive model of loneliness can be integrated into this self-regulatory perspective. Nevertheless, it is evident that empirical testing is needed to see if the suggested mechanisms of the self-regulatory loop can be found in lonely individuals. Besides the further longitudinal observations of loneliness and cognitive and behavioral aspects, it is necessary to include motivational approach and avoidance tendencies in future studies.

Even though, up until now, the focus has been mainly on the inner psychological and individual dynamics of loneliness, it is important to note that the possibility of displaying specific behavior depends on external factors such as sociodemographic, economic, and/or health factors (for a review on factors that go beyond the immediate social environment, see Luhmann et al., 2023). However, these factors go beyond the scope of this dissertation and will not be further discussed. Nevertheless, Caspar (2016) underlined the advantages of the self-regulation perspective in interventions to

address maladaptive self-organized behaviors, which will be discussed in the next section.

4.5.6. Dealing with loneliness loops

The self-regulatory perspective enables the identification of various starting points for alleviating maladaptive loneliness (Skoko & Krieger, in press). For instance, the framework described above can be used to illustrate the adaptive nature of feelings of loneliness, which can contribute to the normalization and destigmatization of adaptive and mostly temporary loneliness and to develop a better understanding of potential approaches to changing existing dysfunctional cognitive and behavioral patterns in social contexts in cases of maladaptive loneliness (Skoko & Krieger, in press). The value of such an understanding of loneliness is supported by previously mentioned findings that suggest approaches aimed at changing maladaptive cognitions in loneliness appear to be most effective (Masi et al., 2011; Zagic et al., 2022). Study IV has also provided promising results by showing reductions in rejection sensitivity and social avoidance behavior, which point towards a less activated avoidance-oriented loop. Further, since the loop of self-regulation is not exclusive to loneliness but has been previously used for explaining self-organized behavior in mental disorders (Caspar, 2016), it is also suitable to incorporate comorbid mental health issues in a therapeutic setting. However, it is important to consider that the context in which the regulatory loops occur may also need to be changed, which could explain the still improvable effects of purely cognitive-behavioral interventions (Skoko & Krieger, in press). This implies that "social interventions" may also be indicated in addition to psychological interventions (Holt-Lunstad, 2018; Mann et al., 2017; Skoko & Krieger, in press).

4.6. Limitations

While providing valuable insights into loneliness and its related cognitive and behavioral aspects, this dissertation encounters several broader limitations that reflect ongoing challenges in the field.

One of this dissertation's primary limitations relates to the generalizability of the findings. All studies used self-selected samples that were predominantly female, highly educated, and consisted only of German-speaking participants, which may limit the generalizability of the findings to more diverse populations. Additionally, potential cultural influences have been neglected, which have been suggested to impact feelings of loneliness (see the framework of norm deviations and loneliness by Heu, 2023). Thus, this points to the need for research with more heterogeneous groups to understand the applicability of the cognitive model of loneliness as well as the implementation of interventions.

The studies relied primarily on self-report measures, which could introduce biases such as social desirability or self-assessment inaccuracies. Future research could benefit from integrating more objective measures of behavioral tendencies (e.g., Elmer et al., 2019) and cognitive biases (e.g., Chen et al., 2020) to enhance the reliability of the findings.

A significant limitation of Study I and II is their cross-sectional design, which restricts the ability to infer causality between loneliness and its associated cognitive and behavioral components. While these studies provide valuable insights into the correlations between variables at a single point in time, they do not clarify the direction of these relationships. Even though Study III employed longitudinal designs, there is a recognition of the limitations inherent in the intervals between measurements and the

potential for different results if continuous or more frequent assessments are used. This suggests that further studies might explore the dynamics of loneliness and its cognitive and behavioral components with finer temporal resolution or underused approaches, such as continuous time models (see Hecht & Zitzmann, 2021).

The field of loneliness research lacks standardized definitions and measurement consistency (Maes & Vanhalst, 2024), making it difficult to compare findings across studies or replicate results. A concerted effort is needed to agree on standard measures and definitions to ensure consistency and reproducibility in loneliness research. In this vein, the approach by Qualter et al. (2021) with the multi-faceted version of the UCLA-LS is promising (i.e., frequency, intensity, and duration). However, this questionnaire has been previously criticized for some items included that might not measure loneliness directly (Maes et al., 2022).

Study IV, involving the ICBT intervention designed to reduce loneliness and its associated cognitive and behavioral elements, faces limitations related to the complexity of the intervention's mechanisms. Although the study demonstrated significant reductions in loneliness and improvements in secondary outcomes, attributing these changes directly to specific components of the intervention remains challenging. The intervention involved multiple modules, including elements aimed at cognitive restructuring, social skills training, and mindfulness practices. Disentangling the effects of these individual components to pinpoint which aspects were most effective in reducing loneliness or impacting related constructs like social avoidance and rejection sensitivity is difficult. This complexity might obscure the understanding of which intervention elements are crucial for triggering changes, suggesting a need for future research to employ factorial designs that can isolate the effects of individual

components of complex interventions like SOLUS-D to optimize interventions aimed at alleviating loneliness.

4.7. Future Directions

Building on previous research and the findings of this dissertation, I provide two general suggestions for future research in loneliness: Firstly, the implementation of a unified definition and operationalization of adaptive and maladaptive loneliness instead of vaguely hinting towards these constructs by solely addressing the duration of loneliness ("transient" vs. "chronic"), which is in vein with Maes and Vanhalst (2024). Secondly, a more nuanced approach to adaptive and maladaptive loneliness, as described by the loops of self-regulation, might be more beneficial in capturing the dynamics found in Study III, for instance. With this in mind, a selection of potential directions for future research on loneliness is presented below to lay the groundwork for deeper investigations into its dynamics and interventions.

The lack of evidence for the temporal dynamics of loneliness and maladaptive cognitive and behavioral tendencies suggested in the cognitive model of loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015) calls for more longitudinal studies. Having said this, the cognitive model does not provide a clear suggestion for the duration of these temporal dynamics. The self-regulatory perspective might be more helpful here since it is suggested that the activation of the comparator can vary in terms of frequency, duration, and accuracy (Caspar, 2016), which means that the comparison between the reference and perceived value might take place several times per day or once and again with longer time intervals. Implementing study designs such as experience sampling methods (ESM) or ecological momentary assessment (EMA) techniques could provide insights into the self-regulatory processes involved in

loneliness with a higher temporal resolution, which might offer a nuanced view of how individuals manage their feelings of loneliness in the context of daily life. However, to capture maladaptive as well as adaptive self-regulatory processes, it is necessary to include some version of approach and avoidance tendencies. For instance, Reissmann et al. (2021) investigated the possibility of increases and decreases in social contacts resulting from state feelings of loneliness through ESM, where they were prompted several times a day to state feelings of loneliness and the number of social interactions. Additionally, the inclusion of approach as well as avoidance motivation (similar to prevention and promotion focus in Mund & Neyer, 2018) might clarify the predictability of (mal)adaptive loneliness.

As has been pointed out, the measurement of loneliness would profit if it included multifaceted approaches, as suggested by Qualter et al. (2021). However, it might not suffice only to include facets such as frequency, intensity, and duration to capture (mal)adaptive loneliness fully. Since previous research (Spithoven et al., 2017) and the results of Study I-IV point towards a close relationship between feelings of loneliness and maladaptive cognitive and behavioral aspects, including such components might be necessary to capture maladaptive loneliness. A new measurement containing the three suggested facets of loneliness, adaptive and maladaptive motivational, cognitive, and behavioral aspects, might be a better solution to assess (mal)adaptive loneliness. Instead of defining a prototype describing which maladaptive tendencies are present in a lonely individual, which has been challenging in the past due to the complexity of loneliness (see Heinrich & Gullone, 2006), such a measurement could result in unique profiles (i.e., a circumplex model) similar to the inventory of interpersonal problems (Horowitz et al., 2000). If a certain amount of

loneliness is present (i.e., a certain threshold of an overall loneliness score that includes frequency, distress, and duration), one or two profiles (i.e., approach- and avoidance-oriented) might depict adaptive and/or maladaptive tendencies regarding motivation, cognition, and behavior. This potential measure might help provide tailored interventions for suffering lonely individuals by showing which (mal)adaptive tendencies are present or not.

Furthermore, the loop(s) of self-regulation (Caspar, 2016) can help provide a framework for therapists and patients to explore maladaptive tendencies and find individual points of entry depending on where disruptions in the self-regulatory processes are found (similar to the suggestion by Käll, Shafran, et al., 2020). As previously mentioned, since this framework is not exclusive to loneliness, it can also be implemented in case of comorbid symptoms such as depressiveness and social anxiety, which provides a high degree of flexibility for therapists.

5. Conclusions

This dissertation advances the understanding of loneliness by examining its cognitive and behavioral aspects and exploring intervention strategies. The findings reveal intricate dynamics of loneliness, particularly its potential adaptive and maladaptive aspects. While interventions, such as ICBT, have shown efficacy, this work underscores the necessity of grasping the underlying processes that contribute to maladaptive loneliness. Recognizing these mechanisms can improve interventions and tailor approaches that address the specific needs of individuals experiencing loneliness. By integrating a self-regulatory framework, this research illuminates potential paths for further exploration, aiming to enhance theoretical knowledge and practical applications in mitigating the impact of loneliness.

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7. Personal contribution statement

The following summarizes Andrej Skoko's contribution to the Petrarca & SOLUS-D project presented in this dissertation.

- Execution of the Petrarca project, including recruitment of participants, data collection, data analysis, and writing the first version of all manuscripts included in the dissertation. PD Dr. Tobias Krieger supervised all these steps.
- Support in the adaptation of the SOLUS-D program where Dr. phil. Noëmi Seewer had the lead.
- Support in the execution of the SOLUS-D project, including data collection and supervision of master's students who worked on the project. PD Dr. Tobias Krieger supervised all these steps.

8. Appendices

Appendix A: Article I

Revisiting the Cognitive and Behavioral Aspects of Loneliness: Insights from Different Measurement Approaches

Skoko, A., Seewer, N., Mund, M., & Krieger, T. (2024). Revisiting the Cognitive and Behavioral Aspects of Loneliness: Insights from Different Measurement Approaches [Manuscript submitted for publication].

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Revisiting the Cognitive and Behavioral Aspects of Loneliness: Insights from Different Measurement Approaches

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Abstract

Loneliness is increasingly recognized as a critical public health issue that profoundly affects psychological well-being and social functioning. This study evaluates cognitive and behavioral differences associated with different facets of loneliness, testing the degree of agreement of three distinct measures of loneliness: frequency of loneliness, connected distress, and chronicity. We divided a sample of 790 German-speaking adults into lonely and not lonely in terms of frequency, distress, and chronicity and then tested for group differences regarding cognitive and behavioral aspects, as proposed by the cognitive model of loneliness while controlling for depressive and social anxiety symptoms. The results indicate fair to substantial agreement between the three measures. Further, we found significant group differences in all components, such as interpretation bias, social avoidance, and self-esteem, with each loneliness measure. Our findings highlight the multifaceted nature of loneliness and underscore the importance of employing diverse measures to fully capture its complexity. This study contributes to a more nuanced understanding of loneliness and its implications, suggesting that interventions should consider the specific dimensions of loneliness to effectively address its cognitive and behavioral ramifications.

Keywords: **loneliness, cognitive model, ancova, assessment**

Revisiting the Cognitive and Behavioral Aspects of Loneliness: Insights from Different Measurement Approaches

1. Introduction

The aim of the present paper is twofold: First, we aim to investigate differences in cognitive and behavioral aspects between lonely and not lonely individuals while controlling for psychopathology. Second, we aim to test a multifaceted approach to measuring loneliness, with which the sample will be divided into lonely and not lonely.

Loneliness is defined as a subjectively distressing emotional state characterized by a discrepancy between the desired and perceived quality or quantity of social relationships (Peplau & Perlman, 1982). While nearly everyone experiences loneliness at some point in their life, for some, it can become an enduring condition with significant negative implications for mental and physical health and even increased mortality, elevating loneliness as a global health priority (Michelle H Lim et al., 2023).

1.1. Adaptive and maladaptive loneliness

Although increased levels of loneliness can have negative health effects, short-term loneliness can prompt individuals to seek out social connections (Reissmann et al., 2021). From an evolutionary standpoint, loneliness is considered to function as a cue indicating endangered social relationships, which should encourage behaviors aimed at reconnecting with existing relationships or establishing new ones (Cacioppo et al., 2014; Qualter et al., 2015). Therefore, loneliness can act as a healthy and adaptive response, signaling the need for changes in one's social life.

However, Maes and Vanhalst (2024) show in their recent review that previous theoretical frameworks and research argue that loneliness in its prolonged/chronic and consequently maladaptive state can be particularly concerning due to its association

with cognitive biases and behavioral tendencies, which are described in the cognitive model of loneliness by Cacioppo and Hawkley (2009). This model suggests that loneliness triggers a cascade of cognitive processes that heighten awareness of social disconnection. These processes include heightened sensitivity to subjective social threats, negative attributions, and biased social information processing, which can lead to maladaptive behaviors such as social withdrawal and increased vigilance toward potential social threats and thereafter maintain or increase feelings of loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015).

1.2. Loneliness and distorted social information processing

In trying to examine empirical evidence for the cognitive model of chronic loneliness (Cacioppo & Hawkley, 2009), Spithoven et al. (2017) used the social information processing (SIP) model (Crick & Dodge, 1994) in their comprehensive review on cognitive biases in lonely individuals, affecting various stages of social information processing, from attention to interpretation and response selection in social situations. They highlighted the tendency of lonely individuals to interpret social information in a negative light, anticipate rejection, and have negative self and others' evaluations, the increased pursuit of avoidance goals, heightened social avoidance/withdrawal behaviors, and fewer social skills, among others (for the detailed review, see Spithoven et al., 2017). More recent findings support the reported tendencies regarding negative interpretation bias (e.g., Lau et al., 2021; Nombro et al., 2022; Okruszek et al., 2021), higher rejection sensitivity (e.g., Gao et al., 2017; Zhou et al., 2020), negative self-evaluation and low self-esteem (e.g., Geukens et al., 2022; Ti et al., 2022), increased social avoidance behavior (e.g., Skoko et al., 2024), and avoidance

motivation (e.g., Saporta et al., 2021). All in all, these findings support the hypothesis that lonely people show distorted social information processing in different areas.

1.3. Bias information processing related to symptoms of depression and social anxiety

Even though loneliness has been shown to be a distinct construct from depression and social anxiety (e.g., Danneel et al., 2020), loneliness has repeatedly been linked to symptoms of depression and social anxiety (e.g., Lim et al., 2016). However, most studies investigating cognitive and behavioral aspects in lonely people did not factor in the associations between loneliness and symptoms of mental disorders such as depression or anxiety disorders. Since there is compelling evidence that depression and social anxiety are related to biased information processing (for social anxiety see Hirsch & Clark, 2004; for depression see Kube et al., 2020), differences in information processing between lonely and non-lonely individuals, consequently, might be driven by differences with regard to depressive and social anxiety symptoms. In this study, we wanted to test whether differences regarding social information processing (cf., Spithoven et al., 2017) are maintained when controlling for psychopathological symptoms such as depressive symptoms and symptoms of social anxiety.

1.4. Assessing loneliness

Due to the complexity and subjective nature of loneliness, it is challenging to measure it accurately. Most studies thus far used the UCLA Loneliness Scale (UCLA-LS; Russell, 1996) to assess loneliness. While the UCLA-LS is most commonly used in loneliness research and seems to be a robust tool for measuring general loneliness, its predominant use has limitations. According to Maes et al. (2022), many items in

loneliness scales, including the UCLA-LS, may not directly measure loneliness but rather related constructs. Moreover, most loneliness measures do not include any timeframe with which reported feelings of loneliness can be referenced (Qualter et al., 2021). These points can potentially compromise the validity of the findings.

Qualter et al. (2021) argue that current research often focuses on the frequency of loneliness, for instance, when using most English versions of the UCLA-LS. Other versions of the UCLA-LS (e.g., Nenov-Matt et al., 2020) or, for example, the Rasch-Type Loneliness Scale (RTLS; de Jong-Gierveld & Kamphuls, 1985) use items with categories that reflect agreement (Maes et al., 2022), which might be interpreted as the intensity. However, Qualter et al. (2021) argue that current measures might primarily address the persistence of loneliness-related emotions and behavior and that exploring its severity may be more effectively conceptualized through intensity (e.g., by explicitly asking about the distress connected to loneliness) or duration (e.g., by asking how long feelings of loneliness lasted), or a combination of these measures. They further point toward that Weiss (1973) argued that both the frequency and intensity of loneliness should be examined. Despite this longstanding recognition of the importance of frequency, intensity, and duration, there is little exploration into which measures best indicate the severity of loneliness, and most scales were developed without this consideration (Qualter et al., 2021).

Direct measurement of loneliness involves asking respondents explicitly if they feel lonely, using one-item questions such as “Do you feel lonely?” which are mostly used in epidemiological studies. Indirect measurements such as the UCLA-LS are multiple-item scales that do not explicitly use the word loneliness. Shiovitz-Ezra and Ayalon (2012) found significant discrepancies between direct and indirect measures of

loneliness, with more than half of respondents who reported loneliness on the direct measure but were classified as not lonely on the indirect measure. Similarly, Nicolaisen and Thorsen (2014) argue that different prevalence rates might emerge due to the heterogeneity of loneliness measures (direct vs. indirect).

The direct single-item measures of loneliness might fail to fully capture the subjective distress of loneliness. To address this, Reinwarth et al. (2023) formulated a single item, which tried to include feelings of distress regarding loneliness to provide a better screening tool for large-scale population study. The single-item was formulated as “I am frequently alone/have few contacts” and could be rated as 0 “no, does not apply”, 1 “yes, it applies, but I do not suffer from it”, 2 “yes, it applies, and I suffer slightly”, 3 “yes, it applies, and I suffer moderately”, or 4 “yes, it applies, and I suffer strongly”. They then summarized the responses of the participants (similar to Beutel et al., 2017) and recoded loneliness by combining 0 and 1 “no loneliness or distress”, 2 “slight loneliness”, 3 “moderate loneliness”, and 4“severe loneliness.” The comparison with the three-item version of the UCLA-LS showed similar prevalence rates. They further found a moderately positive correlation ($\rho = .57$, $p < .001$), which stands in line with previous comparisons between direct single-items and the three-item version of the UCLA-LS (Mund et al., 2023). Despite this comparability, these results further point toward a remaining divergence regarding measurements of loneliness. Here, it can be argued that the single-item might focus on the distress (or intensity) and the UCLA-LS on the frequency of loneliness.

Mund et al. (2023) tested different multi- and single-item (direct and indirect) measures for loneliness and demonstrated that single-item measures of loneliness mostly have high correlations with each other and with multi-item scales, and their

nomological nets align with established measures like RTLS and UCLA-LS. However, some differences emerged from the nomological nets: the UCLA-LS tended to have higher positive correlations with constructs such as neuroticism and depressiveness and negative correlations with, for instance, extraversion life satisfaction compared to the direct single-item (Mund et al., 2023). While this might suggest that indirect measures might capture broader aspects of loneliness, they might have lower specificity than direct approaches. Nevertheless, they also showed that single-item measures are reliable, validating their use as robust tools in loneliness research (Mund et al., 2023).

In sum, these similarities and differences between measuring methods highlight that direct and indirect approaches may capture overlapping facets of loneliness but might also assess diverging aspects, which can lead to variability in the reported prevalence and associated characteristics of lonely individuals. This indicates that it might be necessary to account for different facets for a more holistic view of loneliness.

1.5. Defining maladaptive loneliness

When addressing a maladaptive form of loneliness (Maes & Vanhalst, 2024), there is considerable heterogeneity in the literature. Often, terms such as “prolonged” or “chronic” loneliness are used to distinguish a maladaptive from an adaptive form (e.g., Käll et al., 2020). However, some scholars define maladaptive forms of loneliness based on frequency (e.g., Canham et al., 2016), others based on distress associated with loneliness (e.g., Beutel et al., 2017), and others based on chronicity (e.g., Gong & Nikitin, 2021).

In the context of specifically investigating chronic loneliness, Qualter et al. (2021) pointed out that most loneliness scales typically ask participants about the

frequency of their loneliness, using Likert-type scales from 'never' to 'always.' These scales are then also applied in longitudinal studies to categorize participants into 'not lonely,' 'temporary lonely,' and 'chronically lonely' groups, where the occurrence of a certain level of loneliness at all time points determines the affiliation to one of the categories (e.g. Martin-Maria et al., 2021; Martín-María et al., 2020; Ojagbemi et al., 2021; Shiovitz-Ezra & Ayalon, 2010; Theeke, 2010). These study designs seem to integrate both duration and frequency aspects. However, one potential issue emerging from this is that it is unclear how well chronic loneliness is encompassed in these studies since changes in loneliness between the time points were not captured.

Maes and Vanhalst (2024) suggest that future research should disentangle the duration, frequency, and intensity of loneliness and investigate how these aspects, both individually and in combination, relate to, for instance, health outcomes. Qualter et al. (2021) have already implemented this multi-dimension approach by using an adapted four-item version of the UCLA-LS, where they assessed the frequency, intensity, and duration. For instance, regarding the duration, the item "Do you feel a lack of companionship?" was followed by the question "How long does that feeling last when it occurs?" and answered with these response options "1 = hours, 2 = days, 3 = weeks, 4 = months, 5 = longer". They then employed Latent Class Profile Analyses to identify distinct groups of individuals based on their loneliness experiences. The analysis revealed four groups, each characterized by different levels of loneliness across the three measures. One key finding was that the duration of loneliness, particularly experiences lasting months or years, was critical in distinguishing between these groups (Qualter et al., 2021). This approach highlights the importance of considering multiple dimensions of loneliness to understand its impact fully.

1.6. Current Study

Our study aims to investigate whether the cognitive and behavioral differences between lonely and non-lonely individuals persist when comparing groups of lonely and non-lonely people based on different aspects of loneliness. Specifically, we first applied three different ways of assessing high vs. low lonely individuals: an indirect measurement of loneliness, a direct measurement of loneliness and the connected distress, and chronicity of loneliness. Then, we test the degree of agreement between these three ways, where we expect to find at least a moderate agreement between the three methods. Finally, we examine group differences regarding different cognitive or behavioral aspects of the cognitive model of chronic loneliness, i.e., regarding interpretation bias, rejection sensitivity, social avoidance behavior, distress disclosure, self-esteem, and avoidance goal intensity, between high and low lonely participants for each of the different ways of categorizing, while controlling for depressive and social anxiety symptoms. We expect to find significant differences between the groups regarding all variables. However, this study is mainly exploratory in nature for the two latter categorizations since they are new.

2. Methods

The sample of this cross-sectional study consisted of 790 German-speaking adult participants from the community. To be included in the study, participants had to be 18 years or older and able to read and understand German. The majority of the participants were women (81%), the mean age was 31.86 years (*SD*=12.48); range = 18 – 90), 56.1% were employed, and 47.3% had a university/university of applied sciences degree. Regarding their relationship status, 41.7% were single, 52.3% were in a relationship or married, and 3.4% were divorced or widowed. Participants were

recruited from the general population through recruiting platforms (e.g., SurveyCircle), social media, or internet forums (e.g., www.psychic.de) and were asked to answer questionnaires online via Qualtrics (Qualtrics XM). We titled the survey as a "survey study on loneliness."

2.2. Measures

2.2.1. Loneliness

We assessed high vs. low lonely individuals in three different ways. First, we used the most commonly used way to distinguish lonely vs. non-lonely individuals by a cut-off applied to an indirect measure of loneliness, i.e., a short version UCLA Loneliness scale, which assesses foremost the frequency of loneliness (see Qualter et al., 2021). Second, we created groups of lonely vs. non-lonely individuals based on the distress that is linked to loneliness. Third, we created groups applying the 2-year criterion proposed by Young (1982) to assess the chronicity of loneliness.

Loneliness frequency was measured using the German 9-item version (Luhmann et al., 2016) of the UCLA loneliness scale (UCLA-LS; Döring & Bortz, 1993; Russell, 1996). Sample items are: "How often do you feel that you lack companionship?", "How often do you feel that you have a lot in common with the people around you?". The items were rated on a Likert scale from 1 (never) to 4 (always). Higher scores indicate increased loneliness. The internal consistency in our sample was high (see Table 1). They were asked how often these statements applied to them in the last four weeks. We dichotomized the scale with a cut-off point of ≥ 27 for the analyses, similar to Shiovitz-Ezra and Ayalon (2012). 1, which stands for lonely, and 0 for not lonely.

Loneliness distress was operationalized by using two single-items. Loneliness was assessed with a single direct question ("Do you feel lonely?"; rated on a 4-point

scale with the response options 0 = “no, never”; 1 = “yes, sometimes”; 2= “yes, quite often”; 3 = “yes, very often”). Further, we assessed the feeling of distress caused by loneliness (“To what extent do you feel distressed by the stated feelings of loneliness?”; 0 = “not at all”; 1 = “a little”; 2 = “quite”; 3 = “strongly”; 4 = “very strongly”). Then, we created a dichotomous variable to combine the two variables similar to Reinwarth et al. (2023): a combination of values from 2 to 3 on the loneliness item and values from 2 to 4 on the distress item were coded as 1 (lonely) and the rest as 0 (not lonely).

Loneliness chronicity was operationalized by again using the above-mentioned direct single-item question. For participants who reported feeling lonely at least quite often, we asked for how many months this was already the case. We then created a dichotomous variable with a cut-off value of 24 months in accordance with the definition by Young (1982). 1 stands for chronically lonely, and 0 for not chronically lonely.

2.2.2. Cognitive and behavioral variables related to loneliness

As we have shown above, Spithoven et al. (2017) demonstrated in their review that lonely individuals seem to exhibit cognitive and behavioral differences in regard to social information processing compared to non-lonely individuals. To assess several of those components, we used the following questionnaires:

Interpretation bias in socially ambiguous situations was assessed with the respective subscale of the Interpretation and Judgmental Questionnaire (IJQ; Brettschneider et al., 2015; Voncken et al., 2003). The scale was used in previous studies assessing interpretation bias (Badra et al., 2017; Brettschneider et al., 2015; Miers et al., 2008). The scale consists of social events with positive, ambivalent, mildly negative, or profoundly negative valence. Five brief vignettes were presented for each

valence. Four interpretations for every event were used as the response format, ranging from positive, ambiguous, and mildly negative to profoundly negative, which the participants had to rate for plausibility ("Which of the four answers seems most plausible/appropriate to you?") by ranking them from one (most plausible) to four (least plausible). We used the subscale of ambivalent situations for the analyses. First, the mean rank of the profoundly negative interpretation was calculated over situations. The score is the mean rank given to the profoundly negative interpretation of the scenarios and ranges between 1 and 4. We reverse-coded the ranks, meaning a higher score indicates more negatively biased processing. The internal consistency in our sample was moderate for the socially ambiguous situations (see Table 1).

Social avoidance behavior was measured with a subscale from the Cognitive-Behavioral Avoidance Scale (CBAS; Ottenbreit & Dobson, 2004; Röthlin et al., 2010). For this study, the 8-item behavioral social subscale was used (e.g., "I tend to make up excuses to get out of social activities," "I avoid attending social activities"). The rating consisted of a five-point Likert scale (from 1 = "not at all true for me" to 5 = "completely true for me"), with higher scores indicating increased social avoidance behavior. The internal consistency in our sample was high (see Table 1).

Rejection sensitivity was assessed using the adapted adult version (A-RSQ; Berenson et al., 2009) of the Rejection Sensitivity Questionnaire (Downey & Feldman, 1996). In the A-RSQ, 9 hypothetical interpersonal situations are presented, and respondents indicate how they would feel or think in the stated situations. Participants indicated on a 6-point scale how concerned they would be in that situation (from 1 = "very unconcerned" to 6 = "very concerned") and how likely they would expect to be accepted (from 1 = "very unlikely" to 6 = "very likely"). Those two responses were then

multiplied for each scenario, and afterward, a mean score was calculated with higher values indicating higher rejection sensitivity. The internal consistency in our sample was high (see Table 1).

Comfort with self-disclosure was assessed using the Distress Disclosure Index (DDI; Kahn & Hessling, 2001). It is a 12-item scale designed to measure the degree to which a person is comfortable talking with others about personally distressing information (e.g., "I am willing to tell others my distressing thoughts"). Items are rated on a 5-point Likert-type scale (1 = "strongly disagree" to 5 = "strongly agree"). The sum score was used for the analyses with higher values indicating more comfort with self-disclosure. The internal consistency in our sample was high (see Table 1).

Self-esteem will be assessed using the 10-item revised German version (von Collani & Herzberg, 2003) of the Rosenberg Self-Esteem Scale (RSES; Rosenberg et al., 1989). This scale measures the positive and negative aspects of self-esteem. Items are rated on a 4-point Likert scale (0 = "strongly agree" to 3 = "strongly disagree"). The sum score was used for the analyses, and higher values indicated higher self-esteem. The internal consistency in our sample was high (see Table 1).

Avoidance Goal Intensity was assessed with the Inventory of Approach and Avoidance Goals (IAAM; German: Fragebogen zur Analyse Motivationaler Schemata [FAMOS]; Grosse Holtforth & Grawe, 2000). The original IAAM consists of 94 items; 57 assess the intensity of approach goals, and 37 the intensity of avoidance goals. In the current sample, we only assessed the avoidance goals of the subscales "Aloneness/Separation," which has five items (e.g., "not receiving enough love and attention"), "Deprecation/Derogation," consisting of five items (e.g., "not being respected"), and "Vulnerability," which comprises of three items (e.g., "to show your

own weaknesses"). Items are rated on a 5-point Likert scale (1 = "not at all terrible" to 5 = "extremely terrible"). The mean over the 13 items was used for the analyses, with higher values indicating higher avoidance goal intensity. The internal consistency in our sample was high (see Table 1).

2.2.3. Psychopathological symptoms

Due to the evidence that depression and social anxiety are related to biased information processing (for social anxiety see Hirsch & Clark, 2004; for depression see Kube et al., 2020) and the potential that differences in information processing between lonely and non-lonely individuals might emerge from differences with regard to depressive and social anxiety symptoms, we implemented used the following questionnaires to assess depressive and social anxiety symptoms:

Depressive symptoms were assessed with the 9-item depression module of the Patient Health Questionnaire. All nine items correspond to the nine DSM-IV criteria for depression. The items are rated on a 4-point Likert scale (from 0 = "not at all" to 3 = "nearly every day"). The sum score ranging from 0 to 27 was used for the analysis, with higher scores reflecting higher levels of depressive symptoms.

Symptoms of social interaction anxiety are measured with the German translations of the short-form of the Social Interaction Anxiety Subscale (SIAS-6; Peters et al., 2012). The six items are rated on a 5-point Likert scale (from 0 = "not at all" to 4 = "extremely"). The sum score ranging from 0 to 24 was used for the analysis, with higher scores reflecting higher levels of social interaction anxiety symptoms.

2.3. Statistical Analyses

All analyses were conducted in R (R Core Team, 2022). First, we calculated the bivariate correlations and Cronbach's alpha of all measures. Second, we divided the

sample in three ways: lonely vs. not lonely using the ≥ 18 cut-off of the UCLA-LS, distressed vs. not distressed due to loneliness using the two single items, and chronically lonely vs. not chronically lonely using the self-reported duration of loneliness with the 24-month cut-off. Third, we calculated Pearson's X^2-tests for gender and Welch's two-sample t-tests for age, depressive, and social anxiety symptoms to see if there are significant group differences. Fourth, we tested the degree of agreement between the three division methods using the χ^2 analysis, percentages, Cohen's κ (Cohen, 1960), and r_ϕ. Cohen's κ values are interpreted as follows: values ≤ 0 indicate no agreement, 0.01–0.20 indicate slight agreement, 0.21–0.40 indicate fair agreement, 0.41–0.60 indicate moderate agreement, 0.61–0.80 indicate substantial agreement and 0.81–1.00 indicate almost perfect agreement (Landis & Koch, 1977). r_ϕ values range from -1 to 1, with values closer to 1 indicating a stronger positive correlation. Fifth, we investigated group differences regarding the three distribution methods with gender, age, depressive and social anxiety symptoms, using χ^2-tests for categorical scales and analysis of variance or *t*-tests for the continuous scales. Sixth, we performed three (for each division method) two-sided ANCOVA to test group differences regarding interpretation bias, rejection sensitivity, social avoidance behavior, distress disclosure, self-esteem, and avoidance goal intensity while controlling for depressive and social anxiety symptoms. Finally, we calculated partial *η2* for the effect sizes. To account for false discovery rate due to multiple testing, we implemented the Benjamini-Hochberg correction method (Benjamini & Hochberg, 1995) for the ANCOVAs.

3. Results

3.1 Descriptive statistics and zero-order correlations

Means, standard deviations, medians, ranges, and zero-order correlations of all study variables, as well as Cronbach's alpha of all measures, are presented in Table 1. The zero-order correlations reveal that all three facets of loneliness showed significant associations with all constructs connected to the cognitive model of loneliness. The associations of loneliness frequency, loneliness distress, and loneliness chronicity with interpretations bias, rejection sensitivity, social avoidance behavior, and avoidance goal intensity were significantly positive and negative with distress disclosure and self-esteem.

3.2. Distribution of lonely vs. non-lonely and degree of agreement

In our sample, based on the different approaches, either 15.95 % (frequency), 29.75% (distress), or 19.49% (chronicity) were classified in the lonely group compared to the non-lonely group. Taken together, 65.06% of the participants were categorized as not lonely in all three aspects, 12.03% in one, 15.57% in two, and 7.34% in all three aspect(s).

Overall the χ^2-analyses revealed that the three classification methods are significantly different (see Table 2). The percentage agreement between the loneliness frequency and loneliness distress groups was 78.10%, with a Cohen's κ of .40, indicating almost moderate agreement beyond chance. The r_ϕ for this comparison was .43, suggesting a strong positive association between these groupings. For the loneliness frequency and loneliness chronicity groups, the percentage agreement was 79.74%, with a Cohen's κ of .31, indicating fair agreement. The r_ϕ was .31, suggesting a moderate positive association. The comparison between the loneliness distress and

loneliness chronicity groups showed an 86.96% agreement, with a Cohen's κ of .65, indicating substantial agreement. The r_ϕ for this pair was .68, indicating a strong positive relationship.

Table 2 displays the comparison of the three methods of classification with each other. As for the comparison between frequency and distress, most individuals who did not report loneliness in terms of distress also did not show signs of loneliness frequency (94.23%). A small fraction of individuals who did not report loneliness distress nonetheless exhibited signs of loneliness frequency (5.77%). Over half of the individuals who reported feeling loneliness distress did not show signs of loneliness in terms of frequency (60.00%). Nearly half of the individuals who reported loneliness distress also showed signs of loneliness frequency (40.00%). Regarding the comparison between frequency and chronicity, most individuals who did not show signs of loneliness chronicity also reported not being lonely in terms of frequency (89.62%). A smaller portion of individuals without reporting loneliness chronicity did report loneliness frequency (10.38%). Over half of the individuals who reported longer durations of these feelings did not show signs of loneliness frequency (61.04%). Nearly half of the individuals who show signs of loneliness chronicity also reported loneliness frequency (38.96%). Finally, the comparison between distress and chronicity revealed that a vast majority of individuals who did not report feeling lonely in terms of distress also reported a shorter duration of loneliness feelings (98.02%). A very small proportion of individuals who did not report loneliness distress still reported loneliness chronicity (1.98%). More than a third of individuals who reported feeling loneliness distress indicated a shorter duration of loneliness (39.10%). Most individuals who reported

feeling lonely in terms of distress were also classified as lonely in terms of chronicity (60.90%).

Table 3 shows the distribution of participants in the groups using the three methods, including gender distribution, mean age, and mean values for depressive and social anxiety symptoms, as well as the tests for group differences. For the loneliness frequency lonely vs. non-lonely groups, significant differences were found in terms of age, depressive symptoms, and social anxiety symptoms. Age was significantly higher in the lonely group with more depressive and social anxiety symptoms. Similarly, for the loneliness distress groups, significant differences were observed in terms of age, depressive symptoms, and social anxiety symptoms. The participants who were lonely and distressed were significantly older and had higher levels of depressive and social anxiety symptoms. For the loneliness chronicity group, significant differences were also found in terms of age, depressive symptoms, and social anxiety symptoms. Participants who were chronically lonely were significantly older and had higher depressive and social anxiety symptoms.

3.3. Group differences

Table 4 presents the results of the two-sided ANCOVAs testing the mean differences between lonely vs. non-lonely groups for the dependent variables interpretation bias, rejection sensitivity, social avoidance behavior, distress disclosure, self-esteem, and avoidance goal intensity, with depressive and social anxiety symptoms as covariates, including partial η^2 for the effect sizes.

Regarding the groups based on loneliness frequency, the ANCOVA results indicated significant main effects of loneliness score on all dependent variables (*p*-values < .001). They suggest that lonely vs. non-lonely people, in regard to frequency,

report more interpretation bias (moderate effect), higher rejection sensitivity (large effect), more social avoidance behavior (moderate effect), lower distress disclosure (medium effect), and lower self-esteem (large effect), as well as increased avoidance goal intensity (small effect).

Similarly, significant main effects were also found on all dependent variables for loneliness distress. These findings indicate that higher distress associated with loneliness is linked to greater interpretation bias (medium effect), higher rejection sensitivity (large effect), more social avoidance behavior (medium effect), lower distress disclosure (small effect), and lower self-esteem (large effect), as well as increased avoidance goal intensity (small effect).

Significant effects of chronicity were found on all dependent variables for loneliness chronicity. Chronic experiences of loneliness were significantly related to increased interpretation bias (medium effect), higher rejection sensitivity (large effect), more social avoidance behavior (medium effect), lower distress disclosure (medium effect), and lower self-esteem (large effect), as well as higher avoidance goal intensity (small effect).

4. Discussion

The present study aimed to explore the cognitive and behavioral differences between lonely and non-lonely individuals by incorporating three different aspects of loneliness while controlling for depressive and social anxiety symptoms. Specifically, we built groups of lonely vs. non-lonely people based on frequency, distress, and chronicity. We then tested the degree of agreement between the three methods before comparing lonely vs. non-lonely individuals for the three different ways of conceptualizing lonely versus non-lonely individuals.

4.1. Lonely vs. non-lonely individuals based on frequency, distress, and chronicity

The three methods of group building revealed different distributions regarding who is considered lonely and who is not. To provide a perspective, we are going to compare the found prevalences in our sample with results from previous studies. The prevalence of lonely individuals in terms of frequency (15.95%) was similar to a meta-analysis that looked at global prevalences of loneliness, assessed with the UCLA-LS (~13 %; Surkalim et al., 2022). Further, Surkalim et al. (2022) also looked at prevalences assessed through direct single items, where they found ~5-12% in different adult age groups to be lonely, which was substantially lower than in our sample (29.75%). Further, Reinwarth et al. (2023), who we based our loneliness distress item on, showed that 11.5 % of their German sample reported at least moderate levels of loneliness. These differences might likely be explained through different sample characteristics and a potential self-selection bias that contributed to the higher prevalence in our study. As for the chronicity of loneliness, we did not find any prevalences in other studies coming from the self-reported duration of loneliness. However, Michelle H. Lim et al. (2023) have investigated the prevalence of chronic loneliness through different means. They operationalized chronic loneliness as the occurrence of episodes of loneliness in at least two consecutive measurement waves, which would be at least two years, which has also been implemented in other studies (e.g., Martin-Maria et al., 2021; Martín-María et al., 2020). Compared to our sample (19.49%) they found 13% of participants to be chronically lonely (Michelle H. Lim et al., 2023). What also might contribute to the different prevalences is the fact that we relied on the self-reported duration of feelings of loneliness as a basis, which is an uncommon approach and might highlight a different facet of chronicity of loneliness. In general, the comparisons

suggest that our community sample seems to be lonelier in all three aspects compared to representative samples in previous studies. Specifically, given that we advertised our study as a study on loneliness, people more affected by loneliness might have felt more attracted to participate, while people who consider themselves to be never or only rarely affected by loneliness may not have been interested in a study on this topic.

More participants were classified as lonely with the direct single item connected to distress (29.75%) than with the indirect measure assessing loneliness frequency (15.95%). This stands in line with the findings by Shiovitz-Ezra and Ayalon (2012), who also found higher prevalences of lonely individuals when asked directly. However, this contrasts with most previous studies, which either showed similar distributions (e.g., Reinwarth et al., 2023) or higher when assessed indirectly (e.g., Eccles et al., 2020). This also contradicts findings pointing toward a self-stigma connected with feelings of loneliness (Barreto et al., 2022; Kerr & Stanley, 2021; Lau & Gruen, 1992). As for the degree of agreement between the loneliness frequency and distress method, the results reveal almost moderate to strong agreement. In comparison to the findings of Shiovitz-Ezra and Ayalon (2012), the overlap of participants being categorized as lonely in both terms was bigger. However, over half of the individuals (60.00%) who report feeling lonely in terms of distress (direct measure) do not show signs of loneliness in terms of frequency (indirect measure), which is in line with the findings by Shiovitz-Ezra and Ayalon (2012). The discrepancies regarding the different distributions and degree of agreement with these findings might emerge due to the possibility that when asked directly, individuals may be more likely to acknowledge and report these feelings due to the immediate reflection on their emotional state. This could contrast with indirect measures that assess loneliness more broadly and abstractly, possibly diluting the

immediate emotional impact and leading to lower reported levels of loneliness through indirect measures. Another possibility could be that by using the word “loneliness” in direct measures, individuals can use their own interpretation of loneliness when reporting such feelings. Indirect measures might not account for some of these interpretations, which could mean that certain items do not reflect aspects of an individual’s concept of loneliness. Taken together, these findings suggest that while there is some overlap between the two measurement approaches, each method seemed to capture unique aspects of loneliness and, therefore, led to a different distribution in the two groups.

Our assessment methods for loneliness frequency and loneliness duration revealed distinct distributions, with a higher percentage of participants categorized as lonely when considering chronicity (19.49%) compared to frequency (15.95%). More than half of the participants who were categorized as lonely in terms of chronicity were not lonely in terms of frequency (61.04%). This might suggest that some aspects or impacts of longer periods of loneliness are not always observable through indirect metrics. The fair to moderate degree of agreement also suggests that while there is an overlap, the two approaches might diverge due to unique aspects of loneliness. Yet even though we tried to minimize the risk of memory bias by dichotomizing the duration and only incorporating participants who also felt lonely at least quite often, biases could have still affected the prevalences and the discrepancy of the two measurement approaches.

Our findings indicate that a lower percentage of participants were categorized as experiencing loneliness when assessed for chronicity (19.49%) compared to distress (29.75%). Around 40% of participants categorized as lonely in terms of distress did not

experience feelings of loneliness for longer than two years. However, the other 60% of the participants who reported longer durations of loneliness were categorized as lonely in terms of distress. This is also reflected in the degree of agreement, which indicates a substantial agreement. While the immediacy and salience of emotional distress might lead to higher reporting rates of loneliness distress due to the direct impact on an individual's well-being, most of the participants experiencing loneliness for longer durations also feel the distress connected to loneliness. However, it has to be noted that the overlap might also partially emerge due to the direct single item being involved in the operationalizing of both loneliness distress and chronicity.

Taken together, the distributions and our analysis of the degree of agreement between the three distinct measures of loneliness - frequency, distress, and chronicity - illuminate significant overlaps and divergences that reflect the complex nature of loneliness as a multifaceted construct. The fair to substantial agreement observed between these measures underscores their relative reliability but also highlights the nuances that each dimension captures about the experience of loneliness. This and the fact that some participants have been categorized as lonely in none, one or several aspects of loneliness supports this notion. However, in contrast to previous studies, we did not use common approaches for measuring different facets of loneliness and also did not test for validity and reliability. This further supports nuanced and multi-dimensional approaches to assess loneliness more adequately and uniformly, hopefully (Qualter et al., 2021). However, more research is needed to grasp and fully entangle the nature of loneliness and its different aspects (Maes & Vanhalst, 2024).

4.2. Further support for distorted social information process in lonely people

The results regarding the group differences indicated significant main effects of all three loneliness measures (frequency, distress, and chronicity) on the dependent variables, even after controlling for depressive and social anxiety symptoms. Higher levels of loneliness were associated with greater interpretation bias, rejection sensitivity, social avoidance behavior, lower distress disclosure, and self-esteem, as well as increased avoidance goal intensity. These findings are consistent with the cognitive model of loneliness proposed by Cacioppo and Hawkley (2009) and the findings in the review by Spithoven et al. (2017), which suggest that loneliness triggers maladaptive cognitive and behavioral processes.

Lonely individuals exhibited significantly greater interpretation bias, aligning with previous research demonstrating that they tend to interpret ambiguous social situations negatively (Nombro et al., 2022; Okruszek et al., 2021). This negative bias in interpreting social information can perpetuate feelings of loneliness by reinforcing negative social expectations and reducing the likelihood of positive social interactions.

The significant group differences between loneliness and heightened rejection sensitivity support the notion that lonely individuals are more vigilant for social threats and more likely to expect rejection in social situations (Qualter et al., 2013; Watson & Nesdale, 2012). This hypervigilance can lead to a self-fulfilling prophecy, where the anticipation of rejection increases the likelihood of actual social withdrawal or rejection (Qualter et al., 2015).

Consistent with the cognitive model of loneliness, our results show that higher loneliness in all three terms comes with increased social avoidance behavior. This finding is in line with studies showing that lonely individuals are more likely to engage in

behaviors that avoid social interactions (Coplan et al., 2013; Watson & Nesdale, 2012). This can thereby limit opportunities for social connection and exacerbate feelings of loneliness.

Lonely individuals reported lower levels of distress disclosure, indicating a reluctance to share personal distress with others (Burke et al., 2012; Wei et al., 2005). This lack of self-disclosure can hinder the formation of close, supportive relationships, further isolating lonely individuals and contributing to their ongoing loneliness.

The large effect sizes of the group differences observed for self-esteem across all loneliness aspects suggest that self-esteem is a central feature of all three facets of loneliness. Previous research has consistently found a strong link between loneliness and self-esteem (Geukens et al., 2022; Ti et al., 2022; Vanhalst et al., 2013), indicating that low self-esteem might be reinforcing loneliness. However, there is also the potential for high self-esteem having a buffering effect on loneliness.

Our findings also show that lonely individuals have higher avoidance goal intensity, which stands in line with previous research (Gable, 2006; Park & Baumeister, 2015). This implies that lonely individuals seem more motivated to avoid negative social outcomes than to pursue positive ones. Similarly, Mund and Neyer (2018) found associations between prevention focus (i.e., avoiding harm in social situations) and loneliness. This avoidance orientation can limit their social engagement and opportunities for positive social experiences, further perpetuating loneliness.

In sum, our analyses confirm the substantial impact of loneliness on various cognitive and behavioral outcomes, consistent with the findings in the review by Spithoven et al. (2017). Across the loneliness measures of frequency, distress, and chronicity, we observed significant group differences regarding several cognitive and

behavioral components connected to the cognitive model of loneliness by Cacioppo and Hawkley (2009) while controlling for depressive and social anxiety symptoms. Future research should test how the different components of the cognitive model of loneliness might affect each other over time.

4.3. Defining maladaptive loneliness: an open question

As we circle back to the initial discussion on defining maladaptive loneliness, our results invite reconsidering whether a singular facet of loneliness can wholly encapsulate its maladaptive nature. While the duration has often been used to distinguish adaptive from maladaptive loneliness from a theoretical perspective and implemented in study design, it remains unclear how reliable this conceptualization is. Our results point towards that different aspects of loneliness - frequency, distress, and chronicity - are associated with several maladaptive cognitive and behavioral dispositions, which provides further support for a multi-faceted approach (Maes & Vanhalst, 2024; Qualter et al., 2021). Implementing such an approach might provide distinct profiles, which could lead to a clearer prediction of maladaptive loneliness. Similar to Maes and Vanhalst (2024), we also argue that the inclusion of other cognitive and behavioral constructs, as were implemented in this study, might further help conceptualize maladaptive loneliness since theoretical frameworks suggest the intertwined relationship between them (e.g., Cacioppo & Hawkley, 2009; Qualter et al., 2015). This is further supported by the group differences found in our study regarding all three facets of loneliness. One major gap that remains open is the scarce research regarding the adaptive nature of loneliness (see for review: Maes & Vanhalst, 2024). A better understanding of how loneliness can enhance adaptive cognitions and behaviors might help to paint a clearer picture of how maladaptive loneliness manifests and how

its development might be prevented. In sum, future research should continue to explore these dimensions in concrete to develop more comprehensive models that encapsulate the complex nature of loneliness and investigate the adaptive as well as maladaptive sides in a longitudinal context to potentially grasp the transition from one to the other.

4.4. Implications

Our study underscores the complex and multifaceted nature of loneliness, demonstrating that it encompasses more than the mere frequency. This reinforces the need to consider more aspects of loneliness - such as emotional distress and chronicity - when studying its impacts and developing interventions. Recognizing these diverse dimensions can refine theoretical models and enhance intervention specificity. Further, the development of comprehensive measurement tools that capture the multifaceted nature of loneliness is crucial (Maes et al., 2022; Qualter et al., 2021). These tools should be validated across different cultures and demographics to ensure their sensitivity and accuracy. In clinical practice, our findings suggest that interventions should be multifaceted, addressing the emotional distress and the cognitive and behavioral patterns associated with loneliness and enhancing social skills and self-esteem (Masi et al., 2011; Zagic et al., 2022). Overall, this study highlights the importance of a comprehensive understanding and targeted interventions to effectively address loneliness, contributing to improved mental health outcomes and social connections for those affected.

4.6. Limitations

Despite the strengths of this study, several limitations must be acknowledged. First, the cross-sectional design precludes causal inferences. While we found

significant associations between loneliness and various cognitive and behavioral measures, we cannot determine the directionality of these relationships. Longitudinal studies are needed to establish causality. Second, the sample was predominantly female (81%), which limits generalizability. Third, our sample was relatively young, with a mean age of 31.86 years. Including a wider age range in future studies would provide a more comprehensive understanding of loneliness across different life stages. Fourth, the reliance on self-report measures introduces potential response biases. Participants may have underreported or overreported their feelings due to social desirability or recall bias. Incorporating objective measures could help mitigate these biases. Fifth, we also did not account for all potential confounding variables. While controlling for depressive and social anxiety symptoms, factors like personality traits, social network quality, and recent life events were not considered. Including these factors in future studies would strengthen the findings. Sixth, our operationalization of loneliness chronicity as feelings lasting at least 24 months, while grounded in previous literature (Young, 1982), may not fully capture the nuanced experiences of chronic loneliness. More refined measures of chronicity in longitudinal studies could provide deeper insights. Finally, even though the cut-off points were extracted from previous studies or theories, they remain somewhat arbitrary. Changing these would have also changed the results. Nevertheless, the three methods did not seem to capture the same individuals entirely. Despite these limitations, this study offers valuable insights into the cognitive and behavioral correlates of loneliness, emphasizing the need for a multifaceted approach to understanding and addressing this complex issue.

5. Conclusion

In conclusion, this study provides further support that loneliness, particularly its different facets, is associated with significant cognitive and behavioral maladaptations. These findings underscore the importance of investigating and addressing loneliness as a multifaceted construct and suggest that interventions should focus on cognitive-behavioral components to mitigate its negative effects. Further research, particularly longitudinal studies, is needed to build on these findings, further investigate the distinction between adaptive and maladaptive loneliness and develop effective strategies to combat loneliness and its associated challenges.

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Data availability statement

Data is available on the Open Science Framework (https://osf.io/ftr6b/).

CRediT authorship contribution statement

AS: Investigation, Conceptualization, Formal analysis, Writing – original draft. NS: Investigation, Writing – review & editing. MM: Writing – review & editing. TK: Investigation, Conceptualization, Writing – review & editing, Supervision

Declaration of Competing Interest

The authors have no competing interests to declare that are relevant to the content of this article.

Ethics Approval

This study was approved by the ethics committee of the Faculty of Human Sciences of the University of Bern (2020-08-00005).

Consent

Informed consent was obtained from all individual participants included in the study.

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Table 1

Descriptive statistics and zero-order correlations, including Cronbach's alpha.

Variables	*M*	*SD*	*Mdn*	Range	1	2	3	4	5	6	7	8	9	10	11
Loneliness Frequency	0.16	0.37	0.00	0.00-1.00	(.89)										
Loneliness Distress	0.23	0.46	0.00	0.00-1.00	.43***	-									
Chronic Loneliness	0.30	0.50	0.00	0.00-1.00	.31***	.68***	-								
Interpretation Bias	1.84	0.61	1.75	1.00-4.00	.32***	.31***	.28***	(.63)							
Rejection Sensitivity	9.64	4.69	9.00	1.38-36.00	.41***	.43***	.34***	.55***	(.83)						
Social Avoidance Behavior	19.57	6.73	19.00	8.00-40.00	.30***	.29***	.28***	.47***	.50***	(.87)					
Distress Disclosure	38.29	10.36	38.00	4.00-60.00	-.24***	-.17**	-.14**	-.21***	-.28***	-.37***	(.93)				
Self-Esteem	18.39	7.09	19.00	0.00-30.00	-.37***	-.47***	-.37***	-.48***	-.55***	-.45***	.30***	(.92)			
Avoidance Goal Intensity	3.66	0.55	3.69	1.46-5.00	.14***	.30***	.20***	.14***	.20***	.08*	-.03	-.30***	(.83)		
Depressive Symptoms	10.22	6.21	9.00	0.00-27.00	.35***	.52***	.40***	.34***	.46***	.39***	-.21***	-.69***	.28***	(.88)	
Social Anxiety Symptoms	6.36	5.10	5.00	0.00-24.00	.35***	.37***	.31***	.50***	.53***	.63***	-.28***	-.53***	.21***	.52***	(.85)

Note. Cronbach's alphas are provided in parentheses on the diagonal. Stars indicate the level of statistical significance: * = $p < .05$, ** = $p < 0.01$, and *** = $p < .001$. $N = 790$.

Table 2

Comparison of the three methods of classification

		Frequency		
		Not Lonely	**Lonely**	
Distress	**Not Lonely**	523 (94.23%)	32 (5.77%)	555
	Lonely	141 (60.00%)	94 (40.00%)	235
		664	126	790
		Frequency		
		Not Lonely	**Lonely**	
Chronicity	**Not Lonely**	570 (89.62%)	66 (10.38%)	636
	Lonely	94 (61.04 %)	60 (38.96%)	154
		664	126	790
		Chronicity		
		Not Lonely	**Lonely**	
Distress	**Not Lonely**	544 (98.02%)	11 (1.98 %)	555
	Lonely	92 (39.15%)	143 (60.90%)	235
		636	154	790

Note. Frequency and Distress: $\chi^2(1) = 147.79$, $p < .001$; Frequency and Chronicity: $\chi^2(1) = 73.45$, $p < .001$; Distress and Chronicity: $\chi^2(1) = 360.83$, $p < .001$.

Table 3

Distribution of participants in the groups using three methods, including tests for group differences.

	Loneliness Frequency		***Group Difference Test***
	Lonely	***Not Lonely***	
N	126	664	
Gender (women in %)	79.37%	81.33%	$\chi^2(1) = .08$
Mean Age (SD)	35.25 (14.24)	31.19 (12.02)	$t(160.53) = -3.00$**
Depressive Symptoms (SD)	15.16 (5.93)	9.29 (5.81)	$t(173.64) = -10.22$***
Social Anxiety Symptoms (SD)	10.48 (5.66)	5.58 (4.59)	$t(157.73) = -9.16$***
	Loneliness Distress		
	Lonely	***Not Lonely***	
N	235	555	
Gender (women in %)	79.15%	81.80%	$\chi^2(1) = .576$
Mean Age (SD)	33.69 (13.36)	31.05 (12.02)	$t(402.01) = -2.61$**
Depressive Symptoms (SD)	15.23 (5.79)	8.10 (5.07)	$t(393.15) = -16.40$***
Social Anxiety Symptoms (SD)	9.24 (5.50)	5.14 (4.38)	$t(365.75) = -10.15$***
	Loneliness Chronicity		
	Lonely	***Not Lonely***	
N	154	636	
Gender (women in %)	75.97%	82.23%	$\chi^2(1) = 3.18$
Mean Age (SD)	34.30 (12.96)	31.24 (12.30)	$t(224.44) = -2.65$**
Depressive Symptoms (SD)	15.23 (5.88)	8.81 (5.66)	$t(226.62) = -11.87$***
Social Anxiety Symptoms (SD)	9.56 (5.63)	5.59 (4.64)	$t(206.33) = -8.12$***

Note. Stars indicate the level of statistical significance: * = $p < .05$, ** = $p < 0.01$, and *** = $p < .001$. $N = 790$.

Table 4

Two-sided ANCOVA for testing the mean difference between groups.

Dependent Variables	*Loneliness Frequency*		
	Sum Square	**F**	***partial η²* [95% CI]**
Interpretation Bias	30.10	111.80***	.12 [.08, .17]
Rejection Sensitivity	2987.2	215.19***	.21[.17, .26]
Social Avoidance Behavior	3294.8	122.00***	.13[.09, .18]
Distress Disclosure	4598	47.55***	.06[.03, .09]
Self-Esteem	5455.8	227.11***	.22[.18, .27]
Avoidance Goal Intensity	4.37	15.74***	.02[.01, .04]
	Loneliness Distress		
	Sum Square	**F**	***partial η²* [95% CI]**
Interpretation Bias	28.67	105.41***	.12 [.08, .16]
Rejection Sensitivity	3176.5	224.95***	.22[.17, .27]
Social Avoidance Behavior	2909.2	106.88***	.12[.08, .16]
Distress Disclosure	2387	19.02***	.03[.01 .03]
Self-Esteem	8877.3	370.39***	.32[.27, .37]
Avoidance Goal Intensity	20.87	77.43***	.09[.06, .13]
	Loneliness Chronicity		
	Sum Square	**F**	***partial η²* [95% CI]**
Interpretation Bias	22.20	81.53***	.09 [.06, .13]
Rejection Sensitivity	2014.5	139.58***	.15[.11, .20]
Social Avoidance Behavior	2730.8	126.91***	.11[.08, .16]
Distress Disclosure	1569	15.94***	.02[.01, .04]
Self-Esteem	5424.0	224.00***	.22[.17, .27]
Avoidance Goal Intensity	9.78	35.49***	.04[.02, .07]

Note. Depressive and Social Anxiety Symptoms were implemented as Covariates. Partial η^2 values can be interpreted as such: trivial (< 0.01), small (0.01-0.06), moderate (> 0.06-0.14), and large (> 0.14).*N* = 790.

Appendix B: Article II

Preliminary Investigation of the Regulatory Loop of Loneliness and the Protective Role of Self-Esteem – A Cross-Sectional Study

Skoko, A., Kaeser, J., Seewer, N., & Krieger, T. (2024). Preliminary Investigation of the Regulatory Loop of Loneliness and the Protective Role of Self-Esteem – A Cross-Sectional Study. *Current Psychology*. https://doi.org/10.1007/s12144-024-06185-0

Preliminary investigation of the regulatory loop of loneliness and the protective role of self-esteem – a cross-sectional study

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Abstract

As a major public health issue, chronic loneliness has been associated with increased mortality and impaired physical and mental health. The proposed model by Cacioppo and Hawkley (*Trends in Cognitive Sciences*, *13*(10), 447–454, 2009) pictures the emergence and maintenance of chronic loneliness as a vicious cycle containing cognitive and behavioral aspects. As a potential source of resilience, self-esteem has been shown to have buffering effects on loneliness. This study aimed to investigate the central relationships between the components within the regulatory loop of loneliness and the potential buffering effect of self-esteem. In this study, a community sample of 436 adult participants completed measures of loneliness, interpretation bias in social situations, social avoidance behavior, self-esteem, and important covariates (including depressive and social anxiety symptoms and social network size). First, we tested bivariant correlations. Subsequently, we tested three mediation models representing the regulatory loop of loneliness. Lastly, we tested moderated mediation models with self-esteem as a moderator. Loneliness was positively associated with interpretation bias and social avoidance and negatively with self-esteem. Indirect effects in all three mediation models testing the regulatory loop were positive and strongly significant. Self-esteem was a significant moderator in the mediation models, with higher levels of self-esteem attenuating the indirect effect of loneliness on interpretation bias. These effects held even when controlled for relevant covariates, such as depressive and social anxiety symptoms. This study gives preliminary empirical support for the proposed model of chronic loneliness by Cacioppo and Hawkley (*Trends in Cognitive Sciences*, *13*(10), 447–454, 2009) and the potential buffering effect of self-esteem. Hence, our results support the notion of addressing maladaptive social cognitions and

maladaptive social behavior to effectively reduce chronic loneliness and strengthen self-esteem as a protective factor.

Keywords: Cognitive model; Loneliness; Mediation; Moderation; Self-esteem

Preliminary investigation of the regulatory loop of loneliness and the protective role of self-esteem – a cross-sectional study

1. Introduction

Defined as a discrepancy between the desired and actual quality and/or quantity of social relationships (Peplau & Perlman, 1982), loneliness is a common phenomenon in clinical practice and the public. It represents an emotional and distressing state stemming from the subjective perception of social isolation or when existing relationships fail to meet one's expectations (Heinrich & Gullone, 2006). This emotional state is underlined by an inherent need to belong, comprising a desire to form and maintain positive, lasting, and significant interpersonal relationships (Baumeister & Leary, 1995). Over the years, the attention surrounding loneliness has steadily grown and findings have linked prolonged loneliness to increased mortality and impaired physical and mental health, highlighting loneliness as a global health priority (Lim et al., 2023).

1.1 Regulatory loop of loneliness

Even though prolonged loneliness has been associated with adverse effects on health, transient feelings of loneliness can have an adaptive function. From an evolutionary standpoint, loneliness can be understood as a “social thirst” (Cacioppo et al., 2014), as it can function as a signal pointing to an unfulfilled social need. Therefore, loneliness can promote adaptive behaviors such as reconnecting with people from existing relationships or forming new ones (Cacioppo et al., 2014). Hence, loneliness can be a healthy reaction, indicating that adjustments must be made regarding social life (Cacioppo et al., 2014; Qualter et al., 2015). However, the question arises of how this adaptive nature of loneliness seems to vanish over a more extended period.

Cacioppo and Hawkley (2009) have suggested that loneliness may affect human cognition in maladaptive ways over time. Accordingly, feelings of loneliness arise from experiencing social isolation and/or interpersonal rejection, which can lead to a motivational conflict. The desire to reaffiliate with others and simultaneously the motive to protect oneself from social threats arise, which is assumed to lead to hypervigilance toward social threats and a distorted perception of social situations (Qualter et al., 2015). Especially ambiguous social situations seem to be interpreted as more threatening by lonely people (Qualter et al., 2013). This appears to be based on biased cognitions, which in turn may lead to counterproductive social behaviors and, consequently, reexperiencing negative social situations and loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015).

In their comprehensive review, Spithoven et al. (2017) have examined cognitive aspects of the regulatory loop postulated by Cacioppo and Hawkley (2009) that may lead to prolonged loneliness. They have gathered existing evidence on the relationship between cognitive aspects and loneliness and showed that lonely individuals seem to exhibit negative biases in several areas of social information processing. This distorted information processing appears to manifest itself in an increased attentional focus on socially threatening stimuli, negative evaluations of oneself and others, increased avoidance goals, and enhanced social avoidance behavior, among others (Spithoven et al., 2017). However, most of the findings seldomly include several aspects of the regulatory loop simultaneously (Lau et al., 2021; Okruszek et al., 2021; van Winkel et al., 2017). Hence, what the relationships between the components of the regulatory loop may look like and if the proposed circular structure of the vicious cycle can be empirically confirmed remain to be seen.

1.2 Self-esteem as a potential buffer

Qualter et al. (2015) have extended the regulatory loop with an alternate pathway out of this vicious circle. Arguing for the adaptive nature of loneliness, they propose a possible crossway before the maladaptive (biased) interpretations and the counterproductive behavioral enactment. Following the activated reaffiliation motive, a phase of social withdrawal to monitor social situations and potential social threats can either lead to a regulation of behavior to reconnect or the abovementioned maladaptive cycle (Qualter et al., 2015). However, the question arises, what could promote this adaptive pathway.

In their review, Heinrich and Gullone (2006) highlighted that one of the most pertinent issues of psychosocial problems surrounding loneliness might be its consistent association with low self-esteem in several findings. Similarly, a longitudinal study has not only found negative between-person associations between loneliness and self-esteem but negative within-person effects of loneliness on self-esteem over time as well (Ti et al., 2022). Besides these negative associations with loneliness, self-esteem can also have its merits. At its core, self-esteem can be understood as a global evaluation of the self (Baumeister et al., 2003). High self-esteem is predictive of one's success and well-being in several life domains, even after controlling for prior levels of self-esteem and success (Orth & Robins, 2014). Previous studies have also shown that high self-esteem had not only a buffering effect on loneliness itself but also the effects of loneliness on other constructs, such as life satisfaction and symptoms of depression and anxiety (Baumeister et al., 2003; Çivitci & Çivitci, 2009; Kong & You, 2013; Rossi et al., 2020). This begs the question if self-esteem could play a crucial role in the regulatory loop of loneliness.

While no studies have taken a closer look at this question, other studies have examined the connection between self-esteem, social information processing, and perceived social rejection, which arguably can be seen as conceptual parts of the regulatory loop of loneliness (Rokach, 1988). Numerous of those studies indicate that high self-esteem might be a source of resilience when facing social rejection, which is closely linked to loneliness (Qualter et al., 2015). More specifically, self-esteem seems to moderate the relationship between social rejection and its cognitive evaluations (Ford & Collins, 2010, 2013; Gyurak & Ayduk, 2007; Kashdan et al., 2014). Therefore, the moderation between social rejection and its cognitive evaluation could be similarly found between loneliness and social cognitions. The findings of Geukens et al. (2022) support this notion as they found higher loneliness connected to elevated fear of negative evaluation and lower self-esteem. With the postulated regulatory loop of loneliness in mind, self-esteem might serve as a buffer for the relationship between feelings of loneliness and biased social information processing. Therefore, with self-esteem potentially attenuating this relationship, the chances of engaging in social situations with less avoidance tendencies might grow due to less biased interpretations of social situations.

1.3 The present study

The present study's first aim is to investigate central relationships within the regulatory loop of loneliness. Accordingly, we expect positive relationships between the three components: loneliness, negative interpretation bias in social situations, and social avoidance behavior. These hypotheses account for the reinforcement of loneliness through the behavioral confirmation of lonely individuals' negative social expectations (Cacioppo & Hawkley, 2009). Secondly, to account for the cyclical

structure in which these components lie, three simple mediation models, corresponding to the ones depicted in Figure 1, are tested containing those three constructs, where we expect significant indirect effects in all models. The third aim is to investigate if self-esteem moderates the relationship between loneliness and interpretation bias, with higher self-esteem weakening this connection. Finally, the three conceptual models (see Figure 1) are examined to test the moderating effect of self-esteem on the mediations. Model 1 pictures the relationship between loneliness and social avoidance behavior, mediated by interpretation bias, with self-esteem as a moderator of the relationship between loneliness and interpretation bias. In Model 2, the relationship between interpretation bias and loneliness is pictured, mediated by social avoidance behavior. Lastly, Model 3 pictures the relationship between social avoidance behavior and interpretation bias mediated by loneliness. Since loneliness serves as a predictor for interpretation bias in Model 3, this path also includes the moderating influence of self-esteem.

2. Methods

2.1 Participants and procedure

The sample of this cross-sectional study consisted of 436 German-speaking adult participants from the general public (72.5% females; age (years): *M(SD)* = 32.24 (15.25), *Mdn* = 25.5, range = 18 – 82; occupation: 67% employed, 33% unemployed; highest educational degree: 63.1% university/university of applied sciences, 11.7% higher technical college, 15.1% apprenticeship, 9.9% compulsory school and 0.2% no degree; relationship status: 55.5% unattached, 44.5% in a relationship or married), who completed an online survey (*N* = 424) or a paper-pencil questionnaire (*N* = 12). Participants were recruited through personal connections, social media, or E-mail

directories, and the data collection was fully anonymized. The data collection took place between November 2019 and June 2020. The inclusion criteria were age above 18 years and the ability to understand and write German since the survey was in German. Since we aimed to preliminarily test the dynamics of the cognitive model and the buffering effect of self-esteem in the general public, we did not recruit participants with a specific community in mind. The online survey contained two bogus items designed to detect random responses. At the beginning of the survey, the participants gave their informed consent. After completing the survey, participants could enter a gift card drawing.

2.2 Measures

2.2.1 Loneliness

Loneliness was measured with the German 9-item version (Luhmann et al., 2016) of the UCLA loneliness scale (UCLA-LS; Russell, 1996) with item translations by Döring and Bortz (1993). Sample items are: “How often do you feel that you lack companionship?”, “How often do you feel that you have a lot in common with the people around you?”. The items were rated on a Likert scale from 1 (never) to 4 (always). This short version showed sufficient convergent validity (Luhmann et al., 2016). For the analyses, the mean score over all items was calculated and ranged from 1 to 4 with higher scores reflecting higher levels of loneliness.

2.2.2 Interpretation bias

Interpretation bias in social situations was assessed with the respective subscale of the Interpretation and Judgmental Questionnaire (IJQ; Brettschneider et al., 2015; Voncken et al., 2007). The scale consists of social events with positive, ambivalent, mildly negative, or profoundly negative valence. Five scripts were

presented for each valence. Four interpretations for every event were used as the response format, ranging from positive, ambiguous, and mildly negative to profoundly negative, which the participants had to rate for plausibility ("Which of the four answers seems most plausible/appropriate to you?") by ranking them from one to four. First, the mean rank of the profoundly negative interpretation was calculated over situations with the same valence, resulting in four subscales. The score is the mean rank given to the profoundly negative interpretation of the scenarios and ranges between 1 and 4. After recoding higher score indicates more negatively biased processing.

2.2.3 Social avoidance behavior

Social avoidance behavior was measured with a subscale from the Cognitive-Behavioral Avoidance Scale (CBAS; Ottenbreit & Dobson, 2004; Röthlin et al., 2010). For this study, the 8-item behavior social subscale was used (e.g., "I tend to make up excuses to get out of social activities," "I avoid attending social activities"). The rating consisted of a five-point Likert scale ranging from 1 (not at all true for me) to 5 (completely true for me). The mean score over all items ranging from 1 to 5 was used, with higher scores reflecting higher levels of social avoidance behavior.

2.2.4 Self-esteem

Self-esteem was measured with the 10-item revised German version of the Rosenberg Self-Esteem Scale (RSES; Rosenberg et al., 1989; von Collani & Herzberg, 2003). The questionnaire was answered with a Likert-Scale ranging from 0 (strongly agree) to 3 (strongly disagree) (e.g., "I feel that I'm a person of worth, at least on an equal plane with others", "I feel I do not have much to be proud of"). The mean score over all items ranging from 0 to 3 was used with higher scores reflecting higher levels of self-esteem.

2.2.5 Covariates

As for the covariates, we assessed depressive symptoms with the sum score of 9-item depression module of the Patient Health Questionnaire (PHQ-9; Kroenke et al., 2001; Löwe et al., 2004) symptoms of social interaction anxiety with the sum score of the short-form of the Social Interaction Anxiety Subscale (SIAS-6; Peters et al., 2012), mobility with the corresponding subscale of the Patient Questionnaire for Medical Rehabilitation (IRES-4; Bührlen et al., 2005; Wirtz et al., 2005), social network with the social network index (SNI; Berkman & Syme, 1979; Härtel et al., 1988).

Loneliness is a mainly subjective phenomenon, distinct from objective isolation (Cornwell & Waite, 2009; Peplau & Perlman, 1979). Hence, the relationships presented here should hold even when controlling for objective factors such as the social network size. Reduced mobility can also be such a factor, limiting socialization opportunities, especially in the elderly (Cohen-Mansfield & Parpura-Gill, 2007). Furthermore, there have been bidirectional associations between loneliness and symptoms of mental disorders such as depression or anxiety disorders (Danneel et al., 2020; M. Maes et al., 2019; Santini et al., 2020; Vanhalst et al., 2012). To account for these two factors, potentially leading to objective social isolation and the presence of symptoms of depression or social anxiety, all regression models were calculated with social network size, mobility, and symptoms of depression and social interaction anxiety as covariates. Regarding gender differences, on the one hand, men have been shown to report more loneliness when indirect measures were used, as in the current study (Barreto et al., 2021). On the other hand, a meta-analysis has shown gender differences in loneliness to be close to zero (Marlies Maes et al., 2019). Nevertheless, we included gender as a covariate to account for a potential influence and due to our predominantly

female sample (0 = female, 1 = male). Furthermore, age was incorporated as a covariance even though it has not been shown to be a predictor of loneliness by itself (Luhmann et al., 2023). See Appendix A for detailed descriptions of the questionnaires used to assess the covariates.

2.3 Statistical analyses

Bivariate Pearson correlations were computed to assess the relationship between loneliness, interpretation bias in social situations, and social avoidance behavior. Mediation, moderation, and conditional process analysis were conducted using the PROCESS macro by Hayes (2018) for SPSS. Data cleaning, descriptive and inferential analyses, and graphics production were performed with SPSS 28.0 (IBM Corp., 2021) and R 4.1.2 (R Core Team, 2022). To test the presented models, this study followed the approach of Hayes (2018), firstly separating tests of individual components and secondly integrating testing of all components using conditional process analysis. For this reason, six regression-based analyses were conducted in three stages. First, three simple mediation models were tested. They correspond to the three conceptual models in Figure 1 without the moderating role of self-esteem in Model 1 and Model 3. Second, a simple moderation model was tested where the effect of loneliness on interpretation bias was moderated by self-esteem. Third, for the two conceptual models in Figure 1 containing loneliness as a predictor for interpretation bias (Model 1 and Model 3), the moderation by self-esteem was integrated into the mediation models. This step was only conducted if all previous analyses were consistent with the hypotheses. In these so-called conditional process analyses, the unconditional direct and conditional indirect effects were estimated and tested using inferential methods. All bootstrap confidence intervals were based on 10’000 samples.

3. Results

Table 1 presents the means, standard deviations, ranges, Cronbach's alphas as indicators of internal consistency and intercorrelations for the measures. All correlations were significant and consistent with the first three hypotheses.

3.1 Simple mediation models

Following Model 1 of the conceptual models (see Figure 1), we first evaluated interpretation bias as a mediator of the relationship between loneliness and social avoidance behavior. The corresponding regression equations and a visual representation of the statistical model, including the standardized path coefficients, are displayed in Figure 2. Loneliness affected the reported social avoidance behavior directly as well as indirectly mediated by interpretation bias. Individuals with higher levels of loneliness also reported a higher interpretation bias, and individuals with a higher interpretation bias also reported more social avoidance behavior. The 95% bootstrap confidence interval for the indirect effect was above zero, which indicates that a high level of loneliness partially leads to social avoidance behavior through social interpretation bias.

The second simple mediation model corresponding to Model 2 tested if the positive relationship between interpretation bias and loneliness was mediated through social avoidance behavior. Figure 2 displays the corresponding regression equations and a visual representation of the statistical model, including the standardized path coefficients. Interpretation bias affected loneliness directly as well as indirectly mediated by social avoidance behavior. Individuals who reported higher interpretation bias showed more social avoidance behavior, and individuals with more social avoidance behavior exhibited higher levels of loneliness. The 95% bootstrap interval for

the indirect effect was above zero, which indicates that the effect of interpretation bias on loneliness is partially mediated by social avoidance.

The third simple mediation model corresponding to Model 3 tested the mediation of social avoidance behavior on interpretation bias by loneliness without considering the moderation by self-esteem. The corresponding regression equations and a visual representation of the statistical model, including the standardized path coefficients, are displayed in Figure 2. Social avoidance behavior affected interpretation bias directly as well as indirectly mediated by loneliness. More social avoidance behavior led to a higher degree of loneliness, and higher loneliness led to higher levels of interpretation bias. The 95% bootstrap confidence interval for the indirect effect was above zero, which indicates that the indirect effect of social avoidance behavior on interpretation bias mediated by loneliness is significant. For more detailed results of all mediation models, see Appendix B.

3.2 Simple moderation model

The regression analysis results investigating the moderation of the effect of loneliness on interpretation bias by self-esteem can be found in Appendix C. Of primary interest was the significant regression coefficient of the interaction term Loneliness × Self-esteem (b_3 = -.08, p = .016). Consequently, the effect of loneliness on interpretation bias depended on the level of self-esteem. Figure 3 shows that a higher degree of loneliness was associated with more interpretation bias; this connection was higher in individuals with low self-esteem (M – 1 SD; Simple Slope = .22) than in individuals with high self-esteem (M + 1 SD; Simple Slope = .06).

3.3 Conditional process analyses

The conditional process analysis aimed to integrate the initial moderation analysis in the simple mediation models. The condition that all previous analyses were consistent with the hypotheses was met. In Models 1 and 3 in Figure 1, loneliness serves as a predictor of interpretation bias. Accordingly, the moderating effect of self-esteem on the relationship between loneliness and interpretation bias can be incorporated into these models using the conditional process analysis by Hayes (2018).

Figure 4 visualizes the corresponding unstandardized path coefficients and the conditionality of the indirect effect of loneliness on social avoidance behavior through interpretation bias, where *c'* represents the unconditional direct effect of loneliness on social avoidance behavior and a_3b represents the slope of the conditional indirect effect (Model 1). The 95% bootstrap confidence interval of the slope of the conditional indirect effect (a_3b = -.02) was around zero [−.05, .00]. Hence, the indirect effect of loneliness on social avoidance behavior mediated by interpretation bias was not significantly dependent on the level of self-esteem. However, the probing with 95% bootstrap confidence intervals for low (*M* – *SD*), average (*M*), and high self-esteem (*M* + *SD*) revealed that the conditional indirect effect of loneliness on avoidance behavior mediated through interpretation bias was only significant when self-esteem was low.

The corresponding unstandardized path coefficients and the conditionality of the indirect effect of social avoidance behavior on interpretation bias through loneliness are depicted in Figure 4 (Model 3). In this figure, *c'* represents the unconditional direct effect of avoidance behavior on cognitive bias, and ab_3 represents the slope of the conditional indirect effect. The 95% bootstrap confidence interval of the indirect effect (ab_3 = -.02) was below zero [−.04, −.00]. Therefore, the indirect effect of avoidance behavior on interpretation bias mediated by loneliness depended on the

level of self-esteem. Higher levels of avoidance behavior led to more loneliness and, thus, higher interpretation bias. This connection was stronger in individuals with low self-esteem (*M* – *SD*; Simple Slope of the indirect effect: 0.02) in comparison to individuals with high self-esteem (*M* + *SD*; Simple Slope of the indirect effect: 0.00). The probing with 95% bootstrap confidence intervals for low (*M* – *SD*), moderate (*M*), and high self-esteem (*M* + *SD*) revealed that the conditional indirect effect of avoidance behavior on interpretation bias mediated through loneliness was only significant when self-esteem was low and moderate. For more detailed results of all conditional process analyses, see Appendix D.

4. Discussion

The aims of the present study were first to test the relationships between the components of the postulated regulatory loop of loneliness and second to test the buffering effect of self-esteem on the relationship between loneliness and interpretation bias. The results support our hypotheses concerning the relationships between loneliness, interpretation bias in social situations, and social avoidance behavior. All pathways of the three simple mediation models were significantly positive even when controlling for a variety of covariates, which provide preliminary support for the view of the regulatory loop where the components seem to reinforce each other, leading to a potentially vicious cycle of loneliness (Cacioppo & Hawkley, 2009).

As for the buffering effect of self-esteem, results confirmed self-esteem as a moderator of the positive relationship between loneliness and interpretation bias, with higher self-esteem attenuating this connection. The probing of the interaction revealed that the effect of loneliness on interpretation bias ceased to be significant when self-esteem reached a certain level. Regarding the conditional process analyses, the results support

our hypotheses only to a certain degree. On the one hand, the conditional indirect effect of loneliness on social avoidance behavior partially mediated by interpretation bias was not dependent on self-esteem (Model 1). However, probing the conditional indirect effect revealed a significant dependency of low self-esteem on the mediation. On the other hand, the indirect effect of avoidance behavior on interpretation bias partially mediated by loneliness was dependent on the level of self-esteem (Model 3). The probing revealed that the conditional indirect effect was only significant for low and medium levels of self-esteem. Taken together, the results suggest that low self-esteem increases the effects of loneliness on interpretation bias in social situations, and high self-esteem seems to buffer the effects of loneliness on interpretation bias.

All those results emerged even when accounting for social network size, mobility, gender, age, symptoms of depression, and social interaction anxiety. Interestingly, we observed that the standardized coefficients from symptoms of depression and social interaction anxiety to loneliness in all three models were, in most cases, significant, which underlines the similarities between the constructs but also the importance of distinguishing them from each other (Danneel et al., 2020). Nevertheless, this shows the need to incorporate these two constructs when investigating loneliness.

4.1 Preliminary support for the regulatory loop of loneliness

The results add further preliminary evidence to the proposed relationships of the conceptual model of loneliness introduced in this study (Cacioppo et al., 2009; Qualter et al., 2015). Compared to non-lonely individuals, lonely individuals seemed more prone to distorted interpretations of social situations. Furthermore, these biased interpretations in social situations mediated the relationship between loneliness and

social avoidance behavior. The altered social-cognitive processing of lonely individuals might lead them to engage in different behavioral response patterns than non-lonely individuals, as seen by the positive relationship between interpretation bias in social situations and social avoidance behavior. The effect of biased social-cognitive processing exhibits its effect on promoting further feelings of loneliness through these behavioral consequences and aligns with the conclusion that "lonely individuals may view themselves to be passive victims in their social world, but they are active contributors through their self-protective and paradoxically self-defeating interactions with others" (Cacioppo & Hawkley, 2009). Ultimately, our findings showed that the behavioral pattern of lonely individuals, in turn, is likely to promote further biases in social cognition mediated by loneliness.

In sum, the results support the theorized relationship between affective, cognitive, and behavioral components proposed by current models of loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015; Spithoven et al., 2017). However, the present study did not examine the longitudinal effects with repeated measures over multiple time points of those three components. The regulatory loop hypothesis posits that the effects of these components are likely to manifest over time. Only a few studies have examined those components in a longitudinal design and found no clear evidence for reciprocal effects over time (Lau et al., 2021; van Winkel et al., 2017). Further research needs to address the interaction between the components of the regulatory loop over time and shed light on the mechanisms behind the development of prolonged loneliness.

4.2 Potential buffering role of self-esteem

This study proposed higher levels of self-esteem as a potential buffer of the effect of loneliness on interpretation bias in social situations. As hypothesized, this relationship depended on a person's self-esteem, where higher levels lessened the effects of loneliness on interpretation bias in social situations. The results support and broaden previous research, where high self-esteem had a buffering effect not only on loneliness but also on the effects of loneliness on other constructs (Çivitci & Çivitci, 2009; Kong & You, 2013; Rossi et al., 2020). Yet the results have also shown increased moderating effects of lower levels of self-esteem on the relationship between loneliness and interpretation bias, pointing towards the fact that loneliness evokes different reactions to perceived social rejection depending on self-esteem: Low self-esteem goes hand in hand with an oversensitivity to threats in the relational domain (Leary et al., 1998). Combining these insights with the findings on increased reactivity to social rejection cues (Ford & Collins, 2013), the experience of loneliness may initially be quite stressful regardless of the level of self-esteem. However, individuals seem to process social rejection cues differently depending on their level of self-esteem (Kashdan et al., 2014). Moreover, individuals with low self-esteem recover more slowly from perceived daily rejection situations regarding mental and physical health outcomes, potentially leading to cumulative effects with greater health risks in the longer term (Ford & Collins, 2013). Given that perceived social rejection is a fundamental aspect of loneliness, it is reasonable to suggest that high self-esteem might serve as a protective factor against prolonged loneliness, thereby fostering the evolutionary adaptive function of this emotional state (Qualter et al., 2015).

Additionally, it must be considered that low self-esteem seems to be a risk factor for the development and perpetuation of loneliness as well (Geukens et al., 2022).

Even though the results of the conditional indirect effects are inconclusive, self-esteem seems to have both a buffering and intensifying effect in the mediation models. These results cautiously point towards the view of Qualter et al. (2015) and Spithoven et al. (2017) regarding the regulatory loop's cognitive part as the pivotal point of prolonged loneliness, where protective factors such as self-esteem can be crucial in determining which path an individual follows after experiencing loneliness: the adaptive one, promoting social reconnection, or the one leading into a cycle of negative reinforcement.

4.3 Implications

As already elaborated, loneliness has been linked to increased mortality and impaired physical and mental health (Hawkley & Capitanio, 2015; Holt-Lunstad et al., 2015; Lau et al., 2021; Rico-Uribe et al., 2018), which leads to the conclusion that the need for interventions seems to be evident. It is well known that increasing the number of social contacts alone does not necessarily address the cognitive and affective factors that can perpetuate loneliness (Käll et al., 2020). Recent meta-analyses have shown that interventions aimed at reducing loneliness are most effective when maladaptive social cognitions (e.g., interpretation biases in social situations) and social avoidance behavior are targeted (Masi et al., 2011; Zagic et al., 2022). The findings of the present study support the idea that socio-cognitive processes play a pivotal role in the perpetuation of loneliness. Consequently, interventions should prioritize addressing these processes to combat and alleviate loneliness effectively.

Furthermore, the present results suggest that loneliness interventions might profit from an additional focus on self-esteem, which could theoretically promote the reaffiliation motive and potentially reduce loneliness. Equally to loneliness, cognitive behavior therapy seems to be an effective intervention for increasing self-esteem (Niveau et al., 2021). Therefore, it might be beneficial if interventions tackle loneliness and boost self-esteem simultaneously with a cognitive behavioral approach. However, more studies are needed to evaluate different approaches to interventions addressing loneliness since many current studies have primarily focused on cognitive behavioral therapy and social interventions like social skills training or the enhancement of social support (Masi et al., 2011).

4.4 Limitations

Some critical limitations in the current study need to be addressed. First, since the models tested were based on cross-sectional data only, no causality can be attributed to the reported pathways. Thus, the data needs to be interpreted with caution and caveats. Nonetheless, cross-sectional data does not impede the application of the methods used in this study (Hayes, 2018). Under these circumstances, the results cannot be seen as evidence for the circular relationship but rather as a preliminary indicator that the models are worth exploring in more detail and with longitudinal data to determine temporal associations. Nevertheless, the incorporation of several constructs previously associated with loneliness as covariates provides further support for the results. Second, the probing of non-significant conditional indirect effects can be done as such, but the results must be interpreted cautiously (Hayes, 2015). Third, the sample cannot be seen as representative of the general public in German-speaking countries, mainly due to the predominantly female, highly educated participants. The

age distribution is also not normally distributed and consists mostly of younger participants. A further limitation is that we did not assess ethnicity in the sample. We primarily aimed for a big enough sample size for the analyses regarding the power without considering the representativeness. Lastly, the loneliness model presented here considerably simplifies the actual occurrences surrounding such a phenomenon. The measures used to assess social-cognitive biases (interpretation bias in social situations) and social behavior changes (social avoidance behavior) cannot depict these areas' entire width since they only cover particular aspects of these complex constructs.

5. Conclusion

This study examined the affective, cognitive, and behavioral aspects of the proposed model of chronic loneliness by Cacioppo and Hawkley (2009) and the effect of self-esteem as a buffer. Our results may provide preliminary empirical support for the central relationships depicted in the regulatory loop, which includes loneliness, interpretation bias in social situations, and social avoidance behavior. Furthermore, self-esteem moderated the effects of loneliness on interpretation bias. The present study's findings support the idea that socio-cognitive processes are pivotal in perpetuating loneliness. Consequently, interventions should address these processes to combat and alleviate loneliness effectively. Furthermore, they may also profit from additionally focusing on self-esteem to potentially promote the motive to reaffiliate. Future research should adopt longitudinal designs to further explore and corroborate the present findings over time.

Declarations

Ethics approval and consent to participate

This study was approved by the ethics committee of the Faculty of Human Sciences of the University of Bern (2020-08-00005). The participants gave their informed consent at the beginning of the study.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

AS: Investigation, Formal analysis, Writing – original draft. JK: Investigation, Conceptualization, Formal analysis Writing – review & editing. NS: Writing – review & editing. TK: Investigation, Conceptualization, Writing – review & editing, Supervision

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Tables

Table 1

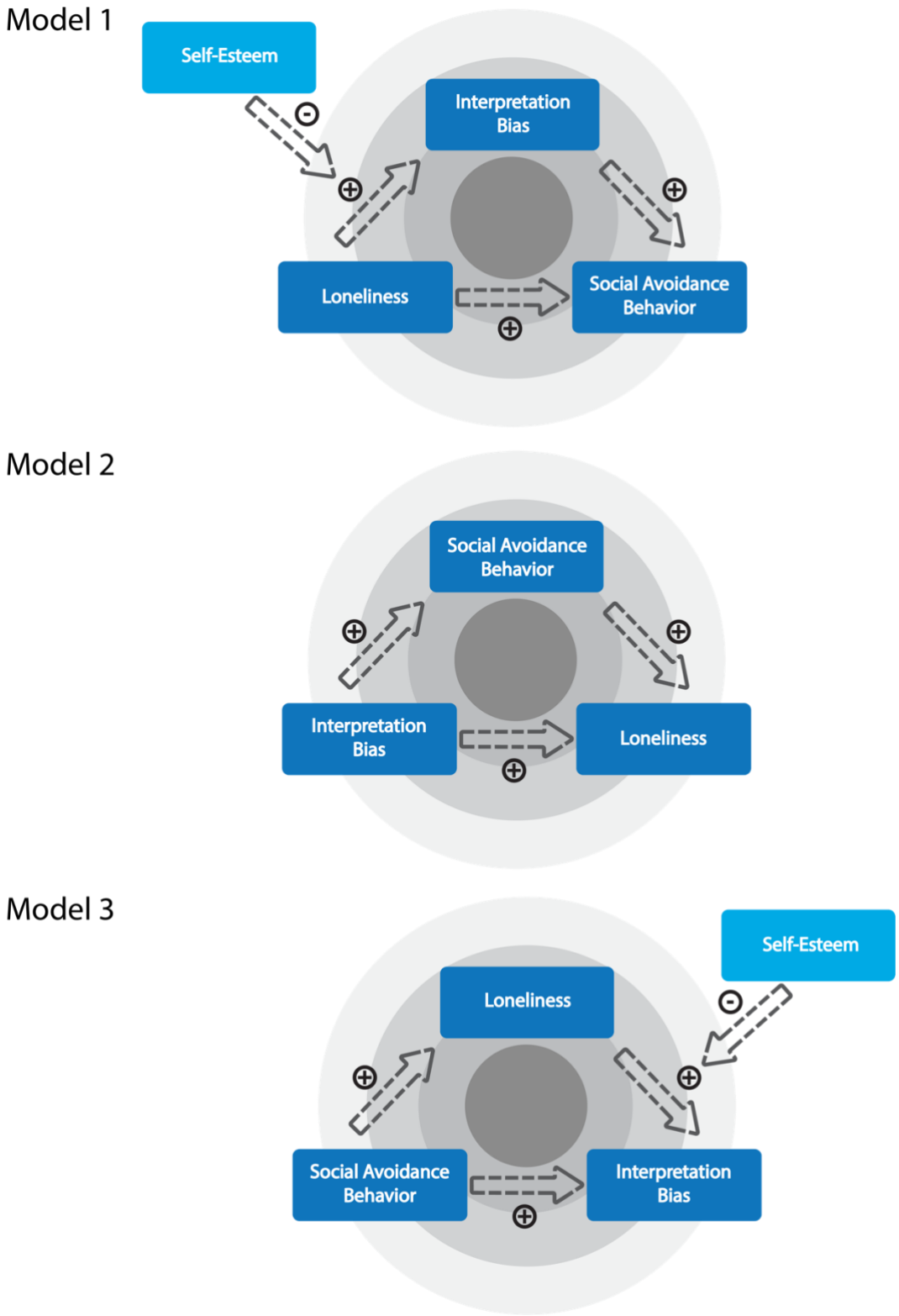
Descriptive statistics and correlations

	Variables	*M*	*SD*	Range	1	2	3	4	5	6	7	8	9	10
1	Loneliness	1.98	0.49	1.00-3.67	(.86)									
2	Interpretation Bias	1.42	0.39	1.00-3.30	**.47**	(.86)								
3	Social Avoidance Behavior	2.01	0.78	1.00-4.50	**.54**	**.47**	(.88)							
4	Self-Esteem	2.14	0.61	0.00-3.00	**-.55**	**-.56**	**-.49**	(.91)						
5	Social Network Size	2.48	0.91	0-4	**-.34**	**-.21**	**-.19**	**.21**	-					
6	Mobility	8.43	1.61	2-10	**-.25**	**-.19**	**-.25**	**.22**	**.14**	(.72)				
7	Depressive Symptoms	6.70	4.76	0-27	**.52**	**.46**	**.50**	**-.62**	**-.25**	**-.32**	(.84)			
8	Social Interaction Anxiety Symptoms	4.30	3.95	0-24	**.51**	**.52**	**.64**	**-.51**	**-.15**	**-.16**	**.54**	(.80)		
9	Gender	-	-	-	**-.10**	.07	-.02	-.04	-.07	**-.11**	.09	.01	-	
10	Age	32.24	15.25	18-82	.07	**-.15**	-.04	**.14**	**-.11**	**-.12**	**-.14**	**-.22**	**-.16**	-

Note. Cronbach's alphas are provided in parentheses on the diagonal. The 95% confidence intervals of the correlations that are displayed in bold do not contain zero. $N = 436$.

Figures

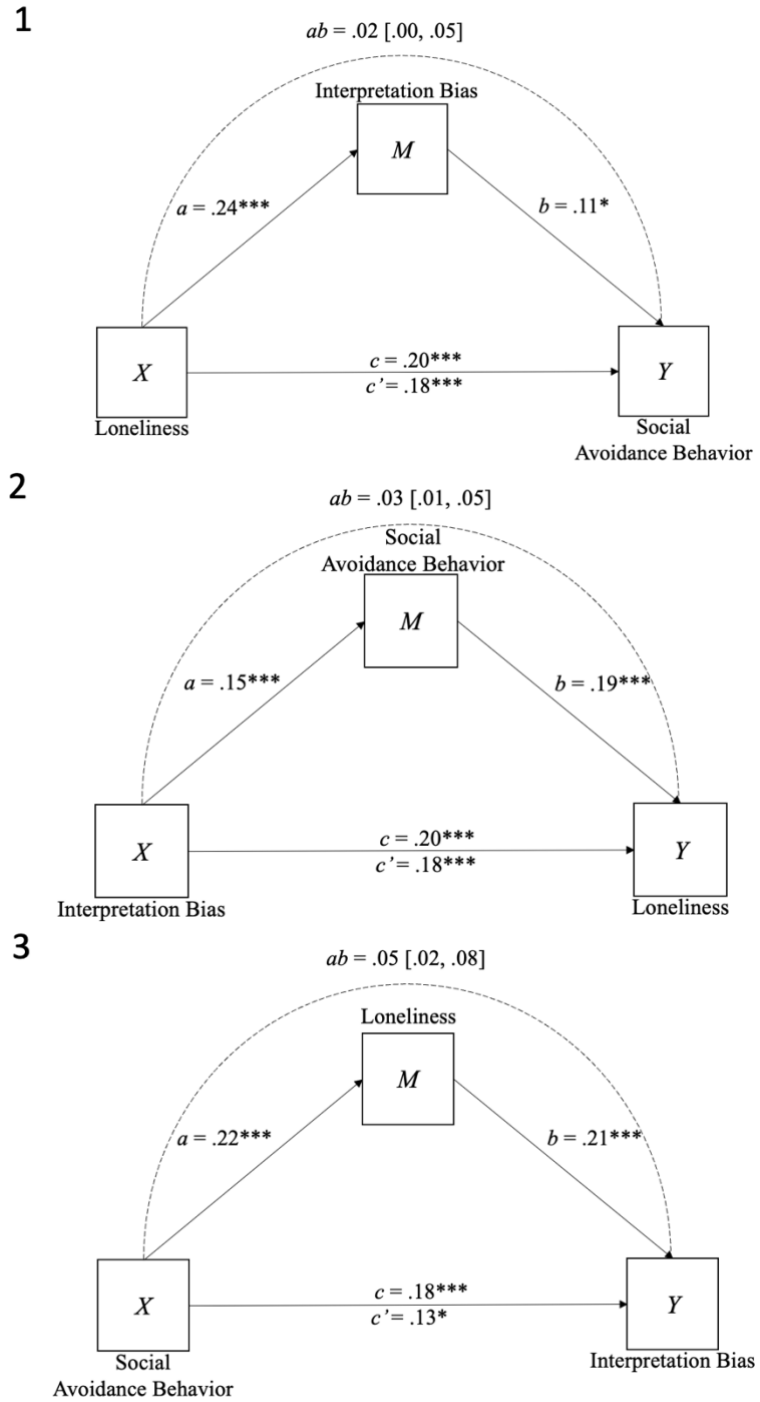
Conceptual models of the proposed relationships in the regulatory loop of loneliness



Note. The solid circles show the postulated signs of the path coefficients corresponding to the arrows.

Figure 2

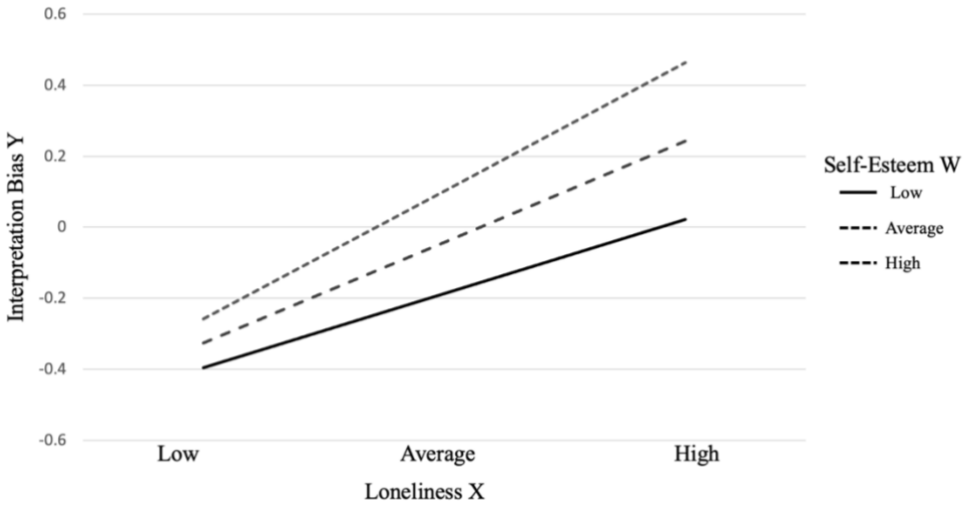
Path coefficients for the simple mediation analysis of Model 1-3 with the corresponding regression equations



Note. For the dotted path representing the indirect effect *ab,* the 95% bootstrap confidence interval is indicated. *c* represents the total effect according to the regression equation $Y = i_Y + cX + e_Y$. To improve readability, control variables (depressive symptoms, symptoms of social interaction anxiety, mobility, social network size, age, and gender) are not shown in the figure. *N* = 436.

Figure 3

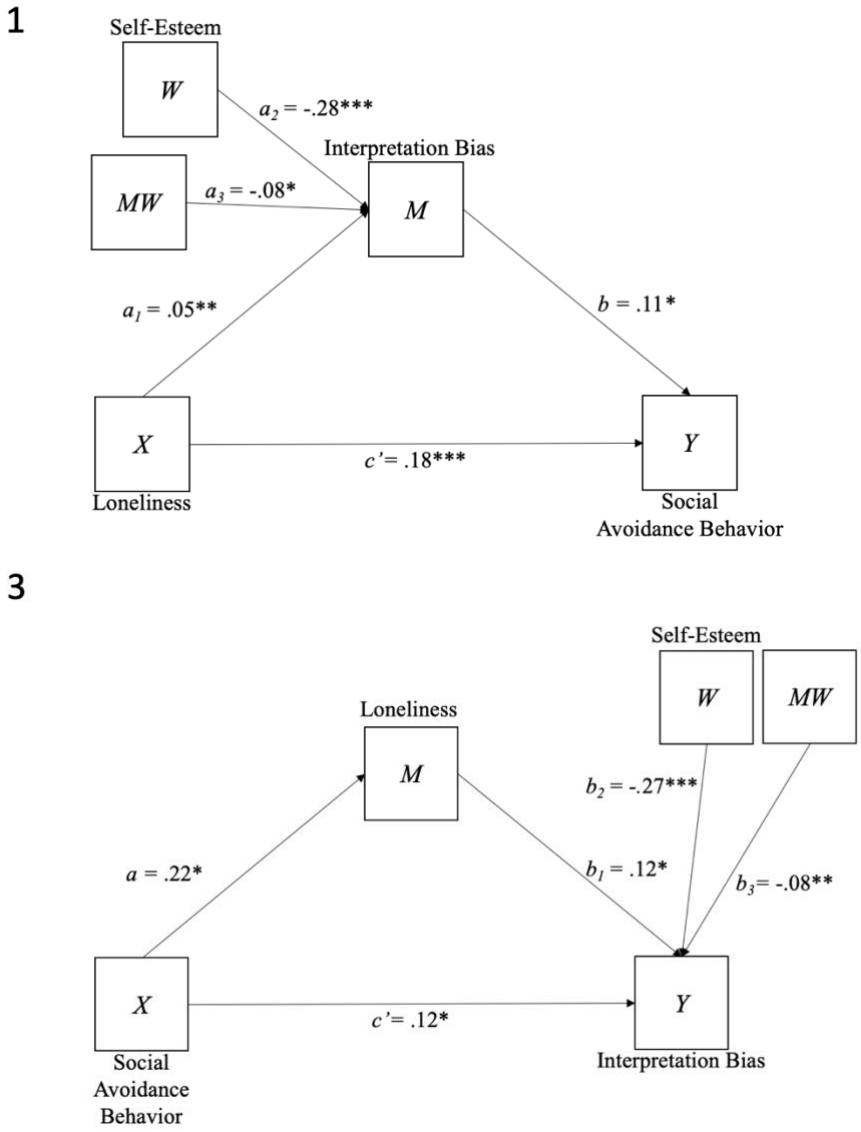
Visual representation: Moderation of the effect of loneliness on interpretation bias by self-esteem



Note. Regression lines for the relationship between loneliness and interpretation bias (standardized) at low levels (*M* − *SD*), average levels (*M*), and high levels of self-esteem (*M* + *SD*). *N* = 436.

Figure 4

Path coefficients for the conditional process analyses of Model 1 & 3 with the corresponding regression equations



Note. To improve readability, control variables (depressive symptoms, symptoms of social interaction anxiety, mobility, social network size, age, and gender) are not shown in the Figure. MW = the interaction of loneliness and self-esteem.

Appendix C: Article III

Untangling the Web of Prolonged Loneliness: A Longitudinal Examination of the Cognitive Model of Loneliness

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Untangling the Web of Prolonged Loneliness: A Longitudinal Examination of the Cognitive Model of Loneliness

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Abstract

Introduction

This study investigated the longitudinal interplay between loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior, using a cognitive model of loneliness as a framework. We expected to find reciprocal prospective effects between all constructs mimicking the cyclic nature of the model.

Methods

We surveyed 785 German-speaking adults over six months at three time points, applying a Cross-Lagged Panel Model (CLPM) and a Random Intercept Cross-Lagged Panel Model (RI-CLPM) containing loneliness, interpretation bias, and social avoidance behavior to discern between- and within-person effects.

Results

CLPM results indicated that initial loneliness predicts increased social avoidance behavior and that more negative interpretation bias leads to increased loneliness and social avoidance behavior. In the RI-CLPM, higher-than-usual loneliness is associated with less-than-usual interpretation bias and vice versa. Further, higher-than-usual loneliness predicted more-than-usual social avoidance behavior and vice versa.

Conclusion

The study highlights the complexity of the emergence of prolonged loneliness, demonstrating that cognitive and behavioral components interact in intricate ways. The results partially support the cognitive model of loneliness, suggesting a nuanced interplay rather than a straightforward cyclic exacerbation. These findings suggest the need for interventions targeting both cognitive and behavioral aspects to address

prolonged loneliness effectively. Future research should employ varied methodologies for a deeper understanding of these dynamics.

Untangling the Web of Prolonged Loneliness: A Longitudinal Examination of the Cognitive Model of Loneliness

1. Introduction

Loneliness, a state of perceived social isolation Cacioppo and Hawkley (2009), has been recognized as a significant public health concern with implications for mental and physical well-being (Holt-Lunstad et al., 2015). More precisely, loneliness emerges from the distressing state of a perceived discrepancy between the desired and actual quality and/or the quantity of social relationships (Peplau & Perlman, 1982). While enduring loneliness has been linked to detrimental health effects (Shiovitz-Ezra & Ayalon, 2010), transient loneliness is theorized to serve an adaptive purpose. From an evolutionary perspective, loneliness is akin to a social thirst, signaling endangered/insufficient social inclusion and, hence, an evolutionary survival threat. This prompts behaviors geared toward reconnecting with existing relationships or forging new ones (Cacioppo et al., 2014; Qualter et al., 2015). Thus, loneliness is assumed to function as a healthy response to social exclusion, signifying a necessity for adjustments in one's social life. However, a critical inquiry arises concerning the apparent fading of this adaptive aspect when loneliness persists over prolonged periods of time.

1.1. Cognitive Model of Loneliness

Cacioppo and Hawkley (2009) proposed that loneliness may gradually influence human cognition in maladaptive ways. The emergence of loneliness stems from experiences of social isolation and/or interpersonal rejection, creating a motivational conflict. Lonely individuals are faced with a simultaneous desire to reconnect with others and a need to shield themselves from potential social threats (Cacioppo &

Cacioppo, 2018; Qualter et al., 2015). This heightened avoidance motivation is thought to induce hypervigilance toward potential social threats and a biased perception of social situations, involving a more negative interpretation of ambiguous social situations, a preference for remembering negative social experiences, and increased attention to indicators of social exclusion (Cacioppo & Hawkley, 2009). This biased perception may ultimately foster counterproductive social behaviors and, consequently, a recurrence of negative social situations and, thus, maintain loneliness (Cacioppo & Hawkley, 2009; Qualter et al., 2015). These relationships have been depicted as a regulatory loop representing a vicious cycle, where loneliness and certain cognitive and behavioral dispositions reinforce each other over time.

The mutual reinforcement between loneliness and cognitive processes has been supported by Spithoven et al. (2017), who proposed a theoretical framework built on the cognitive model of Cacioppo and Hawkley (2009). Specifically, Spithoven et al. (2017) argued that prolonged loneliness may lead to distorted social information processing, including heightened attention towards socially threatening stimuli, negative self and others' evaluations, the increased pursuit of avoidance goals, and heightened social avoidance behaviors, among other (Spithoven et al., 2017). In sum, lonely individuals seem to perceive the world as more threatening. Yet, most of these findings stem from cross-sectional data and often lack longitudinal analyses and the simultaneous inclusion of multiple facets of the cognitive model by Cacioppo and Hawkley (2009).

Further, most studies report between-person effects. However, The model suggested by Cacioppo and Hawkley (2009) can be viewed both from a between- and within-person perspectives. Looking from a between-person perspective, one might

conclude that, for example, people who are lonelier *than others* tend to exhibit more biased cognitions *than others* and, therefore, more avoidance behaviors *than others*. However, when considered from a within-person perspective, for instance, a person who is lonelier *than usual* may also exhibit a more biased interpretation of social situations *than usual*.

1.2. Loneliness and Interpretation Bias

Several aspects of distorted cognition are considered in the model of Cacioppo and Hawkley (2009), as already described. One of those components is the interpretation bias, which is especially relevant for the current study. Interpretation bias refers to a cognitive bias characterized by consistently interpreting (ambiguous) information, often in a negative manner (Hirsch et al., 2016).

Studies indicate that people experiencing loneliness tend to have a biased interpretation of ambiguous social cues, focusing on signals reinforcing their isolation and overlooking opportunities for social connection (Spithoven et al., 2017). This is especially the case with socially ambiguous situations, which encompass ambiguous stimuli that individuals are not sure how to interpret (Schoth & Liossi, 2017). For example, Nombro et al. (2022) have demonstrated that individuals with higher loneliness tend to interpret socially ambiguous situations more negatively. Further, Okruszek et al. (2021) found through path analysis that a hostile interpretation of socially ambiguous situations was associated with of loneliness. However, both studies were cross-sectional in nature. In the longitudinal study of Lau et al. (2021), some evidence has been found that loneliness predicted later biased interpretations of socially ambiguous situations. However, after controlling for concurrent anxiety and depression, this effect became non-significant. Hence, there is some empirical

evidence that cognitive distortions, and more specifically, interpretation bias, are positively linked to loneliness, while there is a need for more longitudinal data.

1.3. Loneliness and Social Avoidance Behavior

As for the relationship between prolonged loneliness and behavioral aspects in the context of the cognitive model (Cacioppo & Hawkley, 2009), some studies have looked at social avoidance and/or social withdrawal tendencies. For instance, Nurmi and Salmela-Aro (1997) have shown that higher reported usage of pessimistic-avoidance strategies in social situations (e.g., avoiding group situations) is associated with more loneliness, even after controlling for previous levels of loneliness in younger adults. This implies that lonely individuals tend to expect a negative outcome in social situations and prefer to avoid similar scenarios. Such avoidance tendency might stem from actual negative experiences in social situations, which influence the perception of future social encounters. In this vein, a recent study by Gong and Nikitin (2021) showed that college students with higher levels of prolonged loneliness report more perceived negative social behavior for both themselves and others. Similarly, Qualter et al. (2015) argue that lonely individuals seem to perceive social situations as more negative and threatening, which can lead to a tendency for social avoidance behavior. With this skewed perception of social situations, maladaptive and counterproductive behavior, such as avoidance or social withdrawal, seems to be more prevalent in lonely individuals. Preece et al. (2021) support this notion with their cross-sectional study, where in the context of emotion regulation strategies, lonely individuals tended to use strategies such as expressive suppression and regulation of emotions by actively withdrawing from others. While these findings point toward the connection between loneliness and social avoidance behavior, further longitudinal research is needed to

examine whether this notion also holds over time and, thus, may constitute a mechanism for maintaining loneliness.

1.4. The Present Study

Even though several studies support the link between loneliness and interpretation bias and social avoidance behavior separately, it generally remains unclear how the components of the cognitive model of loneliness influence each other over time in a vicious cycle, as proposed by Cacioppo and Hawkley (2009). Trying to cast light upon this, the present study aims to investigate the longitudinal interplay between the components of the cognitive model of loneliness over time. Particularly, we wanted to examine the longitudinal effects of loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior at three time points by using two types of structural equation models (SEM).

One type of SEM that has been used for longitudinal studies is the Cross-Lagged Panel Model (CLPM), which captures the prospective effect of one variable on another while accounting for the effect the variable has on itself (Kearney, 2017). There are several instances where longitudinal studies investigating loneliness have implemented CLPMs, where these cross-lagged effects were the focal interest to test the long-term effects of loneliness and other constructs and vice versa (e.g., Cacioppo et al., 2010; Geukens et al., 2023; Griffin et al., 2022; Lau et al., 2021). However, over the last decade, the CLPM has been criticized since, among other reasons, the model might be biased when the investigated variables contain stable inter-individual differences (Hamaker et al., 2015). These stable inter-individual differences have to be taken into account because (chronic) loneliness has been shown to have trait-like characteristics (Griffin et al., 2022; Lim et al., 2016; Mund et al., 2020).

To tackle this issue, Hamaker et al. (2015) introduced the Random Intercept Cross-Lagged Panel Model (RI-CLPM). Here, a latent variable representing the trait-like aspect of a construct is extracted from each variable in the model, which, in contrast to the CLPM, clearly separates between- and within-person effects. However, Orth et al. (2021) argue that alternatives to the CLPM, such as the RI-CLPM, only estimate within-person prospective effects and that between-person effects might only be investigated through correlations. Therefore, they promote the CLPM for research questions investigating prospective between-person effects. Further, Orth et al. (2021) recommend using both the CLPM and the RI-CLPM when both between- as well as within-person effects are aimed to be investigated.

Besides the lack of longitudinal studies regarding the cognitive model of loneliness in general, no studies to our knowledge investigated between- and within-person effects between the components. For this reason and following the recommendation of Orth et al. (2021), we implemented a CLPM for addressing between-person effects and the RI-CLPM for the within-person effects. In order to mimic the regulatory loop (Cacioppo & Hawkley, 2009) in which each construct enhances the other over time, we hypothesize finding significant and positive cross-lagged effects between loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior in both the CLPM and RI-CLPM.

2. Methods

2.1. Participants and Procedure

The sample consisted of 785 German-speaking adult participants. To be included in the study, participants had to be 18 years or older and able to read and understand German. The majority of the participants were women (81%), the mean age

was 31.86 years (*SD*=12.50); range = 18 – 90), 55.9% were employed, and 47.3% had a university/university of applied sciences degree. Regarding their relationship status, 41.6% were single, 52.4% were in a relationship or married, and 3.3% were divorced or widowed. Participants were recruited from the general population through recruiting platforms (e.g., SurveyCircle), social media, or internet forums (e.g., www.psychic.de) and were asked to answer three surveys online via Qualtrics (Qualtrics XM) over six months with an interval of three months. At the beginning of the first survey, participants gave their informed consent and were asked to generate an identification code with which we were able to link the data from the three time points. We will refer to the time points as T1, T2, and T3 in the following. After completing the first assessment, participants were invited to leave their e-mail addresses to be contacted for assessment at T2 and T3. To ensure anonymity, the e-mail addresses were stored in a separate database which did not include the identification codes. We included 785 participants who answered all items at T1. Of those 785 participants at T1, 447 completed the survey at T2 (56.8%) and 405 at T3 (51.5%). After merging the three time points with the identification code, 326 individuals for T2 and 306 individuals for T3 remained. To explore the potential impact of attrition, we assessed differences in loneliness, interpretation bias in socially ambiguous situations, social avoidance behavior, age, and gender between participants who completed the final assessment (T3) and those who dropped out before this assessment. We found no significant differences in any of the self-report variables between participants who dropped out and those who completed the full study. This study was approved by the ethics committee of the Faculty of Human Sciences of the University of Bern (2020-08-00005).

2.2. Measures

Loneliness was measured using the German 9-item version (Luhmann et al., 2016) of the UCLA loneliness scale (UCLA-LS; Döring & Bortz, 1993; Russell, 1996). Sample items are: “How often do you feel that you lack companionship?”, “How often do you feel that you have a lot in common with the people around you?”. The items were rated on a Likert scale from 1 (never) to 4 (always). Higher scores indicate increased loneliness. The internal consistency in our sample was high (see Table 1).

Interpretation bias in socially ambiguous situations was assessed with the respective subscale of the Interpretation and Judgmental Questionnaire (IJQ; Brettschneider et al., 2015; Voncken et al., 2003). The scale was used in previous studies assessing interpretation bias (Badra et al., 2017; Brettschneider et al., 2015; Miers et al., 2008). The scale consists of social events with positive, ambivalent, mildly negative, or profoundly negative valence. Five brief vignettes were presented for each valence. Four interpretations for every event were used as the response format, ranging from positive, ambiguous, and mildly negative to profoundly negative, which the participants had to rate for plausibility (“Which of the four answers seems most plausible/appropriate to you?”) by ranking them from one (most plausible) to four (least plausible). We used the subscale of ambivalent situations for the analyses. First, the mean rank of the profoundly negative interpretation was calculated over situations. The score is the mean rank given to the profoundly negative interpretation of the scenarios and ranges between 1 and 4. We reverse-coded the ranks, meaning a higher score indicates more negatively biased processing. The internal consistency in our sample was moderate for the socially ambiguous situations (see Table 1).

Social avoidance behavior was measured with a subscale from the Cognitive-Behavioral Avoidance Scale (CBAS; Ottenbreit & Dobson, 2004; Röthlin et al., 2010). For this study, the 8-item behavioral social subscale was used (e.g., "I tend to make up excuses to get out of social activities," "I avoid attending social activities"). The rating consisted of a five-point Likert scale ranging from 1 (not at all true for me) to 5 (completely true for me), with higher scores indicating increased social avoidance behavior. The internal consistency in our sample was high (see Table 1).

2.3. Statistical Analyses

All analyses were conducted using the lavaan package (Rosseel, 2012) in R (R Core Team, 2022). We handled missing values and non-normality of the measures with a robust full information maximum likelihood (FIML) procedure.

We estimated two types of structural equation models to examine the cross-lagged effects between loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior. First, we implemented a latent Cross-Lagged Panel Model (CLPM) to estimate between-person effects. To ensure the validity of our latent CLPM and that the constructs are consistently measured across the time points, we first conducted measurement invariance testing across time points (Finkel, 1995). For the latent variable representing loneliness, we used three parcels, including three items each, where items were allocated based on the three-factor structure found by Hawkley et al. (2005) in the long version of the UCLA-LS. As for interpretation bias, we randomly divided the ranks of the five scenarios of the IJQ into two parcels, one of which contained three and the other two items. Regarding social avoidance behavior, the items of the CBAS were calculated on two parcels containing four items, where the items were randomly assigned. We then tested the difference of fit between a

configural model, where only the first indicator was set equal over time, and a metric model, where all indicators were set equal over time for each construct. As for the CLPM, we allowed correlated uniqueness over time for each construct. Autoregressive paths and cross-lagged effects between the three latent variables were specified. Correlations, computed specifically within each time point, were employed to capture the concurrent relationships between latent variables, while correlated residuals accounted for associations between observed variables beyond the latent constructs. Equality constraints were applied to specific parameters for hypothesis testing.

Further, a Random Intercept Cross-Lagged Panel Model (RI-CLPM) with the same constructs as in the CLPM was also run to test within-person time-lagged association while extracting the trait-like aspects of those constructs. We implemented the RI-CLPM provided in the publication of Mund and Nestler (2019), which are based on the works of (Hamaker et al., 2015). We loaded the scores of the measures (observed variables) on phantom latent variables with which autoregressive paths and cross-lagged effects between those three variables were specified. We did not use "true" latent variables (i.e., containing multiple indicators as proposed by Mulder and Hamaker (2021)) because the model did not converge. The RI-CLPM encompassed three random intercept factors, representing the trait-like levels of the three constructs (i.e., loneliness, interpretation bias, social avoidance) over all time points. Correlations were calculated within each time point to capture concurrent relationships among the variables. Error variances of the observed variables were constrained to zero to indicate that all variance in the observed variables is accounted for by the phantom latent variables. All analysis scripts are available at https://osf.io/qk4er/.

To determine the model fit of the CLPM and the RI-CLPM, we used the following fit indices: Comparative Fit Index (CFI; Bentler, 1990), Root Mean Square Error of Approximation (RMSEA; Steiger & Lind, 1980), Standardized Root Mean Square Residual (SRMR; Bentler, 1995; Jöreskog & Sörbom, 1981), and the normed model χ^2 (χ^2/df; Hooper et al., 2007). As for the cut-off criteria for a good model fit, we refer to Hu and Bentler (1999), which are as follows: CFI above .95, RMSEA below .6, and SRMR below .8. As for the normed χ^2, the value should be below 2 (Ullman, 2001). Further, the effect sizes of the cross-lagged effects of the two models are interpreted according to the suggestion by Orth et al. (2022).

3. Results

Descriptive information for all three variables and the zero-order correlations across all time points, including Cronbach's alpha, are displayed in Table 1. All constructs showed moderate to high correlations between each other across all time points and the correlation were highly significant (p <.001).

3.1. Measurement Invariance

The fit indices of the invariance tests are displayed in Table 2; note that we only tested configural and metric invariance as the mean structure (i.e., scalar invariance) was not of interest for the current analyses. The measurement invariance testing for loneliness revealed acceptable fit to the data (see Table 2). The metric model showed a slight decrease in fit. However, the chi-squared difference test indicated that this decrease was not statistically significant ($\Delta\chi^2$ = 9.38, Δdf = 6, p = .154), suggesting that the factor loadings for loneliness are invariant and that the construct is consistently measured across the assessed time points. For interpretation bias, the configural and the metric models yielded a good fit (see Table 2). However, a significant worsening in

the model fit was observed from the configural to the metric model ($\Delta\chi^2 = 10.39$, $\Delta df = 4$, $p = .034$). This significant difference suggests that the factor loadings for interpretation bias may not be entirely consistent across time points; however, given that overall fit inidices are still very good even when imposing metric invariance, we decided to keep this model in the analysis. In the case of social avoidance behavior, both the configural and the metric invariance models indicated a good fit (see Table 2). Interestingly, the metric model showed a slight improvement in fit. However, the chi-squared difference test between these models was not statistically significant ($\Delta\chi^2 = 1.18$, $\Delta df = 4$, $p = .881$), suggesting that the measurement of Social Avoidance Behavior is consistent across time points.

3.2. Cross-Lagged Panel Model

Figure 1 depicts simplified versions of both models with significant cross-lagged effects highlighted. All autoregressive and cross-lagged effects of both models, including standard errors and *p*-values, as well as the specific values for all model fit indices, are displayed in Table 3. Furthermore, Table 4 contains the correlations within each time-point between the latent variables of both models as well as the random intercepts.

The CLPM showed a good fit according to the CFI, RMSEA, SRMR, and the χ^2/df (see Table 3). All autoregressive effects were significant and positive (see Table 3). As for the correlations of the latent variables within the time points, loneliness and interpretation bias only correlated positively at T1, loneliness and social avoidance behavior at all time points, and interpretation bias and social avoidance behavior at T1 and T2 (see Table 4).

Summarizing all cross-lagged effects of the CLPM (see Table 3), loneliness did not predict later interpretation bias (T1 - T2: β = .01, *p* = .842, T2 - T3: β = .01, *p* = .842). However, loneliness did predict later social avoidance behavior, demonstrating medium effects (T1 - T2: β = .07, *p* = .027; T2 - T3: β = .07, *p* = .028). Earlier interpretation bias significantly predicts later loneliness with large effects (T1 - T2: β = .12, *p* = .009; T2 - T3: β = .12, *p* = .010) and predicts later social avoidance behavior with a medium effect (T1 - T2: β = .10, *p* = .015; T2 - T3: β = .10, *p* = .016). Prior social avoidance behavior did not significantly predict later loneliness (T1 - T2: β = .02, *p* = .604; T2 - T3: β = .02, *p* = .604) or later interpretation bias (T1 - T2: β = -.09, *p* = .098; T2 - T3: β = -.09, *p* = .090).

3.2. Random-Intercept Cross-lagged Panel Model

The RI-CLPM showed a good fit according to the CFI, RMSEA, SRMR, and the χ^2/df (see Table 3). The autoregressive effects were only significant for loneliness between the time points (see Table 3). Regarding the correlations between the constructs within each time point, only loneliness and social avoidance behavior positively correlated at all time points (see Table 4). Furthermore, all random intercepts representing the trait-like aspects of the constructs had significant and positive correlations with each other (see Table 4).

Synthesizing the cross-lagged effects of the RI-CLPM (see Table 3), earlier loneliness surprisingly predicted less interpretation bias at a later time point with large effects (T1 - T2: β = -.20, *p* = .030, T2 - T3: β = -.20 *p* = .020), and earlier interpretation bias predicted less loneliness at a later time point with large effects (T1 - T2: β = -.22, *p* = .005 T2 - T3: β = -.20, *p* = .004). Further, earlier loneliness positively predicted later social avoidance behavior with large effects (T1 - T2: β = .24, *p* = .013, T2 - T3: β = .24, *p* = .009), and earlier social avoidance behavior predicted more loneliness with large

effects (T1 - T2: β = .15, *p* = .043, T2 - T3: β = .13, *p* = .046). However, earlier interpretation bias did not predict later social avoidance behavior (T1 - T2: β = -.11, *p* = .129, T2 - T3: β = -.10, *p* = .202), and prior social avoidance behavior did not predict later social avoidance behavior (T1 - T2: β = -.11, *p* = .144, T2 - T3: β = -.10, *p* = .154).

4. Discussion

The present study aimed to test prospective reciprocal effects between the components of the cognitive model of loneliness by Cacioppo and Hawkley (2009) focusing on the interplay between loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior over time. Our findings shed light on the complex dynamics of prolonged loneliness and its cognitive and behavioral correlates, offering insights into both between- and within-person effects.

4.1. Between-Person Perspective of the Cognitive Model of Loneliness

The correlations and autoregressive effect of the CLPM coincide with some previous findings. For instance, the significant correlations between all three constructs at T1 support previously identified relationships between loneliness, interpretation bias, and social avoidance behavior (Spithoven et al., 2017). The autoregressive effects of all three constructs further suggest stability over time, indicating their potential trait-like character. This aligns with the finding that the rank order of loneliness is as stable as the rank order of personality traits over the lifespan (Mund et al., 2020).

As for the CLPM (between-person effects), we did not find reciprocal cross-lagged effects between all three constructs. Specifically, although earlier experiences of interpretation bias predicted increased loneliness and social avoidance behavior at subsequent time points, and initial loneliness predicted heightened social avoidance

behavior over time, we did not find evidence of reciprocal relationships between all constructs as initially hypothesized. This contradicts the expectation that loneliness, interpretation bias, and avoidance behavior would cyclically exacerbate each other. Therefore, the results only partially support the cognitive model of Cacioppo and Hawkley (2009). It seems that the interplay of the between-person effects of loneliness and cognitive and behavioral aspects is not as straightforward as suggested.

Despite the initial association between loneliness and interpretation bias, which was also found by Nombro et al. (2022), loneliness may not be a driving factor behind such biased social cognitions, as was found in the study of Lau et al. (2021). However, the significant prospective effect from interpretation bias to increased loneliness aligns with the cognitive model of loneliness (Cacioppo & Hawkley, 2009), suggesting that individuals who interpret social cues negatively are more likely to experience increased loneliness over time. This predictive relationship stands in line with previous findings (Okruszek et al., 2021).

Moreover, the predictive effect between loneliness and increased social avoidance behavior is consistent with the cognitive model's assertion that loneliness can lead to maladaptive social behavior. This reliance on maladaptive social behavior has also been found in previous studies (Nurmi & Salmela-Aro, 1997; Preece et al., 2021) with lonely individuals showing increased withdrawal from social situations or avoidance strategies in social contexts. However, while such behavior might be a response to loneliness, our results suggest that they do not necessarily exacerbate loneliness over time. Nonetheless, it should be mentioned that social avoidance behavior also did not lead to reduced loneliness, suggesting a potential indirect effect:

due to avoidance behavior, the possibility of corrective social interactions is minimized, which could lead to the maintenance of loneliness.

Furthermore, the positive effect of interpretation bias on social avoidance behavior aligns with the idea of the cognitive model of loneliness that negative social cognitions can lead to maladaptive behavioral responses (Cacioppo & Hawkley, 2009). Yet, social avoidance behavior did not predict later interpretation bias, which might indicate that the development of interpretation biases is more strongly influenced by internal cognitive processes than the behavior of avoiding social situations. In general, these results suggest that from a between-person perspective, social avoidance behavior might rather be a consequence of both higher loneliness and interpretation bias.

In sum, we found evidence supporting some of the suggested pathways of the cognitive model of loneliness (Cacioppo & Hawkley, 2009). However, our results also suggest that instead of reinforcing each other over time in a cyclic manner, the relationship between loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior seems more nuanced. In particular, interpretation bias plays a significant role in influencing loneliness and social avoidance behavior. Further research is needed to replicate the current findings to better understand the interplay between loneliness with cognitive and behavioral components of the cognitive model of loneliness (Cacioppo & Hawkley, 2009).

4.2. Within-Person Perspective of the Cognitive Model of Loneliness

Similar to the findings of the CLPM, the correlations of the intercept factors of loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior were significant and positive, which coincides with previous findings

(Spithoven et al., 2017). However, significant occasion-specific correlations were only found between loneliness and social avoidance behavior at all time points, indicating that higher-than-usual loneliness is cross-sectionally associated with higher-than-usual avoidance behavior. Regarding the autoregressive pathways, only loneliness had significant and positive effects, indicating a notable and consistent within-person stability of loneliness.

As hypothesized, we did observe reciprocal cross-lagged effects between loneliness and interpretation bias using a RI-CLPM. Surprisingly, those effects indicated that higher-than-usual loneliness is associated with *less*-than-usual interpretation bias (and vice versa). Hence, while the existence of the effect was in line with our hypothesis, its direction was not. Further, higher-than-usual loneliness predicted more-than-usual social avoidance behavior; this finding aligns well with the mechanisms suggested by the cognitive model of loneliness (Cacioppo & Hawkley, 2009).

The contradictory findings that higher-than-usual loneliness predicted lower-than-usual interpretation bias at later points and vice versa do not replicate the suggested mechanisms of the cognitive model of loneliness (Cacioppo & Hawkley, 2009) and challenge its postulated straightforward reciprocity. It is plausible that transient fluctuations in loneliness may trigger adaptive cognitive processes or coping mechanisms to facilitate reaffiliation (Qualter et al., 2015). According to Qualter et al. (2015), loneliness activates a reaffiliation motive: the drive to satisfy one's need to belong. Arguably, the elevation of state loneliness, which triggers this motive, might lead to adjustments in cognitive biases by decreasing state interpretation bias. This potential reappraisal process might be a coping strategy where negative interpretations are adjusted to be more neutral or positive to facilitate social connections.

Alternatively, the intensified desire for reconnection triggered by elevated state loneliness might lead individuals to a decreased fear of rejection. This could lead to an indirect reduction of interpretation bias since the reaffiliation motive might outweigh the fear of rejection.

The converse path, where higher levels of state interpretation bias predicted lower state loneliness over time, seems to be even more challenging to interpret since no previous findings support these results. However, from the same motive-oriented perspective as before, individuals driven by the reaffiliation motive and with heightened state interpretation bias might become more vigilant about their social interactions. This hypervigilance and increased attention to social cues (even though negatively skewed) in lonely individuals has been described in the cognitive model of loneliness and also identified in past research (Cacioppo & Hawkley, 2009; Spithoven et al., 2017). It might paradoxically make lonely individuals more attuned to their social needs and potential opportunities for social engagement. However, we note that given the unexpected direction, these findings require replication using different research designs, such as experience sampling, to achieve a higher resolution of the investigated mechanisms.

Further, the results revealed positive reciprocal cross-lagged effects between social avoidance behavior and loneliness. This suggests that higher-than-usual levels of loneliness predict heightened tendencies for social avoidance behavior than normal, and engagement in social avoidance behavior reinforces and exacerbates loneliness, which is consistent with the cognitive model of loneliness (Cacioppo & Hawkley, 2009). Similarly, previous cross-sectional findings point toward lonely individuals tending to rely on active social withdrawal in the context of emotion regulation (Preece et al.,

2021). Further cross-sectional data also suggest that social avoidance behavior positively predicts loneliness (Zhang et al., 2024). Interestingly, this effect found in the RI-CLPM differs from the one found in the CLPM, where loneliness predicted later social avoidance behavior but not vice versa. Moreover, the cross-lagged effects between interpretation bias and social avoidance behavior were non-significant in both directions, suggesting that these two constructs seem to share distinct dynamics with loneliness on the within-person level.

In sum, the results of the RI-CLPM do partially support the suggested pathways of the cognitive model of loneliness (Cacioppo & Hawkley, 2009). The model reveals expected results regarding the significant and positive within-person cross-lagged effects from loneliness to social avoidance behavior and vice versa and unexpected results regarding the reciprocal within-person effects between loneliness and interpretation bias, which at first glance seem contradictory to the cognitive model of loneliness (Cacioppo & Hawkley, 2009). Even though the results can be cautiously interpreted in the context of the reaffiliation motive (Qualter et al., 2015), further research is warranted to replicate these findings to justify the potential reconsideration of the cognitive model of loneliness from a within-person perspective.

4.3. Limitations

This study has some limitations that need to be acknowledged. First, it must be considered that the cognitive and behavioral components of the cognitive model of loneliness could be operationalized with other measures than the ones used in this study. It could be that not only behavioral avoidance but, for example, submissive-hostile behavior in social situations (e.g., Segel-Karpas & Ayalon, 2020) leads to an increase in loneliness. Second, the moderate internal consistency and the lack of full

metric invariance for interpretation bias suggest caution in interpreting the temporal dynamics of this construct in the CLPM analysis since differences in factor loadings across time points indicate potential variations in how interpretation bias is understood or manifested over time. However, the metric model still exhibited a strong fit, and the χ^2 statistics are known to be highly sensitive to large sample sizes, often leading to the detection of minor discrepancies as statistically significant (Putnick & Bornstein, 2016). Third, regarding the three-month interval between the time points, it is not clear when exactly and how the changes in the trait-like constructs occurred. Luhmann et al. (2014) suggest that longitudinal studies should use more frequent or continuous assessments with short enough time lags to learn about the rate and sequence of changes in traits. Similarly, regarding the counterintuitive results of the RI-CLPM, it is unclear whether the time interval might be too large to reliably capture the within-person dynamics of the cognitive model of loneliness (Cacioppo & Hawkley, 2009). It might thus be interesting to test these dynamics with intensive longitudinal settings and using continuous-time models (see Hecht & Zitzmann, 2021). Fourth, the reliance on self-report measures introduces the possibility of common method bias. Future studies might consider objective measures for the behavioral aspect of the model (e.g., Elmer et al., 2019). Finally, the sample, predominantly consisting of highly educated women, may limit the generalizability of our findings to broader populations. Notwithstanding these limitations, our study is the first to our knowledge that provides valuable insights into the longitudinal dynamics of loneliness and its cognitive and behavioral underpinnings with a large sample size, where both between- and within-person effects are considered.

4.4. Implications

The findings from both the CLPM and RI-CLPM in our study provide valuable insights into the dynamics of loneliness, interpretation bias in socially ambiguous situations, and social avoidance behavior. These results have several broader theoretical and practical implications for understanding and addressing loneliness.

Overall, our results suggest a more dynamic and perhaps less deterministic interplay between loneliness, interpretation bias, and social avoidance behavior than what might be predicted according to the cognitive model of loneliness (Cacioppo & Hawkley, 2009). Noteworthy is the difference in cross-lagged effects between the two models, underlining the importance of considering both between-person and within-person perspectives in the longitudinal research of loneliness, as different patterns emerged at each level.

In correspondence with the cognitive model of loneliness, prior meta-analyses have suggested that interventions aimed at changing maladaptive social cognitions and behavior are the most effective in reducing loneliness (Masi et al., 2011; Zagic et al., 2022). Our results support this notion by showing that biased cognitions and social avoidance behavior play a crucial role in the dynamics of prolonged loneliness from a between- and within-person perspective. A recent study tested an online training tool to modify interpretation biases in lonely young adults (Riddleston et al., 2023). It highlights promising results, showing that such interventions, which solely target interpretation biases, might consequently reduce feelings of loneliness. Nevertheless, our results suggest a more intricate dynamic between loneliness and cognitive and behavioral aspects, and, therefore, a more holistic approach could be more promising. Further research is needed to solidify this notion.

5. Conclusion

To our knowledge, the current study is the first to examine the cognitive model of loneliness suggested by Cacioppo and Hawkley (2009) with its interplay of cognitive and behavioral aspects in a longitudinal setting. The results highlight the complexity of prolonged loneliness as a multifaceted phenomenon influenced by both stable traits and transient states. The suggested cyclic pathways depicted in the cognitive model of loneliness were not fully replicated, thus indicating a more intricate and less straightforward dynamic between loneliness, interpretation bias, and social avoidance behavior. Further, our study reinforces implementing interventions tackling cognitive as well as behavioral components to alleviate loneliness. Future research should use intensive longitudinal designs to investigate the dynamics of loneliness and incorporate different aspects of the cognitive model of loneliness (Cacioppo & Hawkley, 2009). A better understanding of the interplay between factors contributing to the development and maintenance of prolonged loneliness might consequently inform research on interventions to alleviate loneliness and help to reduce the mental health burden associated with chronic loneliness.

CRediT authorship contribution statement

AS: Investigation, Conceptualization, Formal analysis, Writing – original draft. NS: Investigation, Writing – review & editing. MM: Formal analyses, Writing – review & editing. TK: Investigation, Conceptualization, Writing – review & editing, Supervision

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Data availability statement

Data is available on the Open Science Framework, including the analysis syntax of the CLPM and RI-CLPM (https://osf.io/qk4er/).

Declaration of Competing Interest

None.

Permission to reproduce materials

No copyrighted materials were reproduced.

Preregistration

The present study was not preregistered.

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Table 1

Descriptive statistics and zero-order correlations, including Cronbach's alpha.

					Loneliness			Interpretation Bias			Social Avoidance Behavior		
Variables	*M*	*SD*	*Mdn*	Range	T1	T2	T3	T1	T2	T3	T1	T2	T3
Loneliness													
T1	20.91	5.42	21.00	9.00-36.00	(.89)								
T2	19.98	5.49	19.00	9.00-35.00	.81	(.90)							
T3	19.51	5.58	19.00	9.00-35.00	.77	.84	(.90)						
Interpretation Bias													
T1	1.84	0.60	1.75	1.00-3.80	.42	.32	.41	(.63)					
T2	1.77	0.58	1.60	1.00-4.00	.39	.40	.44	.63	(.63)				
T3	1.79	0.60	1.60	1.00-3.75	.37	.30	.42	.64	.74	(.66)			
Social Avoidance Behavior													
T1	19.53	6.73	19.00	8.00-40.00	.47	.46	.46	.47	.37	.40	(.87)		
T2	18.48	6.44	18.00	8.00-40.00	.49	.50	.49	.38	.44	.42	.75	(.87)	
T3	19.06	6.73	18.00	8.00-40.00	.47	.53	.56	.48	.48	.49	.77	.81	(.87)

Note. Cronbach's alphas are provided in parentheses on the diagonal. None of the 95% confidence intervals of the correlations contained zero. N_{T1} = 785, N_{T2} = 326, N_{T3} = 306.

Table 2

Fit indices of the CFA models for testing measurement invariance

	χ2	*df*	*p*	CFI	TLI	RMSEA	BIC	AIC
Loneliness								
configural	92.51	17	<.001	.974	.946	.075	6308.61	6135.98
metric	101.47	23	<.001	.973	.958	.066	6277.57	6132.94
Interpretations Bias								
configural	2.67	2	.263	.999	.994	.021	5331.06	5214.42
metric	12.70	6	.048	.992	.980	.038	5314.43	5216.45
Social Avoidance Behavior								
configural	7.69	2	.021	.997	.980	.060	5239.38	5122.73
metric	8.84	6	.183	.999	.997	.025	5213.86	5115.88

Note. Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Root Mean Square Error of Approximation (RMSEA), Standardized Root Mean Square Residual (SRMR), Bayesian Information Criterion (BIC), and Akaike Information Criterion (AIC). $N = 785$.

Table 3

Summary of the CLPM and R-CLPM Autoregressive and Cross-Lagged Pathways, including the Model-Fit

	CLPM			*RI-CLPM*		
	β	*SE*	*p*	β	*SE*	*p*
Autoregressive Pathways						
L1 — L2	**.79**	.03	<.001	**.27**	.10	.008
L2 — L3	**.82**	.03	<.001	**.28**	.13	.024
IB1 — IB2	**1.01**	.07	<.001	.12	.15	.403
IB2 — IB3	**1.00**	.06	<.001	.11	.15	.468
SA1 — SA2	**.75**	.04	<.001	-.06	.14	.685
SA2 — SA3	**.80**	.04	<.001	-.05	.11	.663
Cross-Lagged Pathways						
Loneliness and Interpretation Bias:						
L1 — IB2	.01	.04	.842	**-.20**	.10	.030
L2 — IB3	.01	.04	.842	**-.20**	.09	.020
IB1 — L2	**.12**	.05	.009	**-.22**	.07	.005
IB2 — L3	**.12**	.05	.010	**-.20**	.06	.004
Loneliness and Social Avoidance Behavior:						
L1 — SA2	**.07**	.03	.027	**.24**	.10	.013
L2 — SA3	**.07**	.03	.028	**.24**	.09	.009
SA1 — L2	.02	.04	.604	**.15**	.07	.043
SA2 — L3	.02	.04	.605	**.13**	.06	.046
Interpretation Bias and Social Avoidance Behavior:						
IB1 — SA2	**.10**	.04	.015	-.11	.08	.192
IB2 — SA3	**.11**	.05	.016	-.10	.08	.202
SA1 — IB2	-.09	.05	.098	-.11	.08	.144
SA2 — IB3	-.09	.05	.090	-.10	.06	.154
Model Fit Measures	**CFI** = .979	**RMSE** = .033	**SRMR** = .057	**CFI** = .996	**RMSE** = .029	**SRMR** = .042
	χ^2/df = 1.86	**df** = 158		**χ^2/df =** 1.68	**df** = 15	

Note: L = loneliness, IB = interpretation bias, SA = social avoidance behavior, with numbers standing for the time points (T1, T2, T3). Standardized values are reported. SE refers to the standard error. Significant coefficients are in bold. *N* = 785.

Table 4

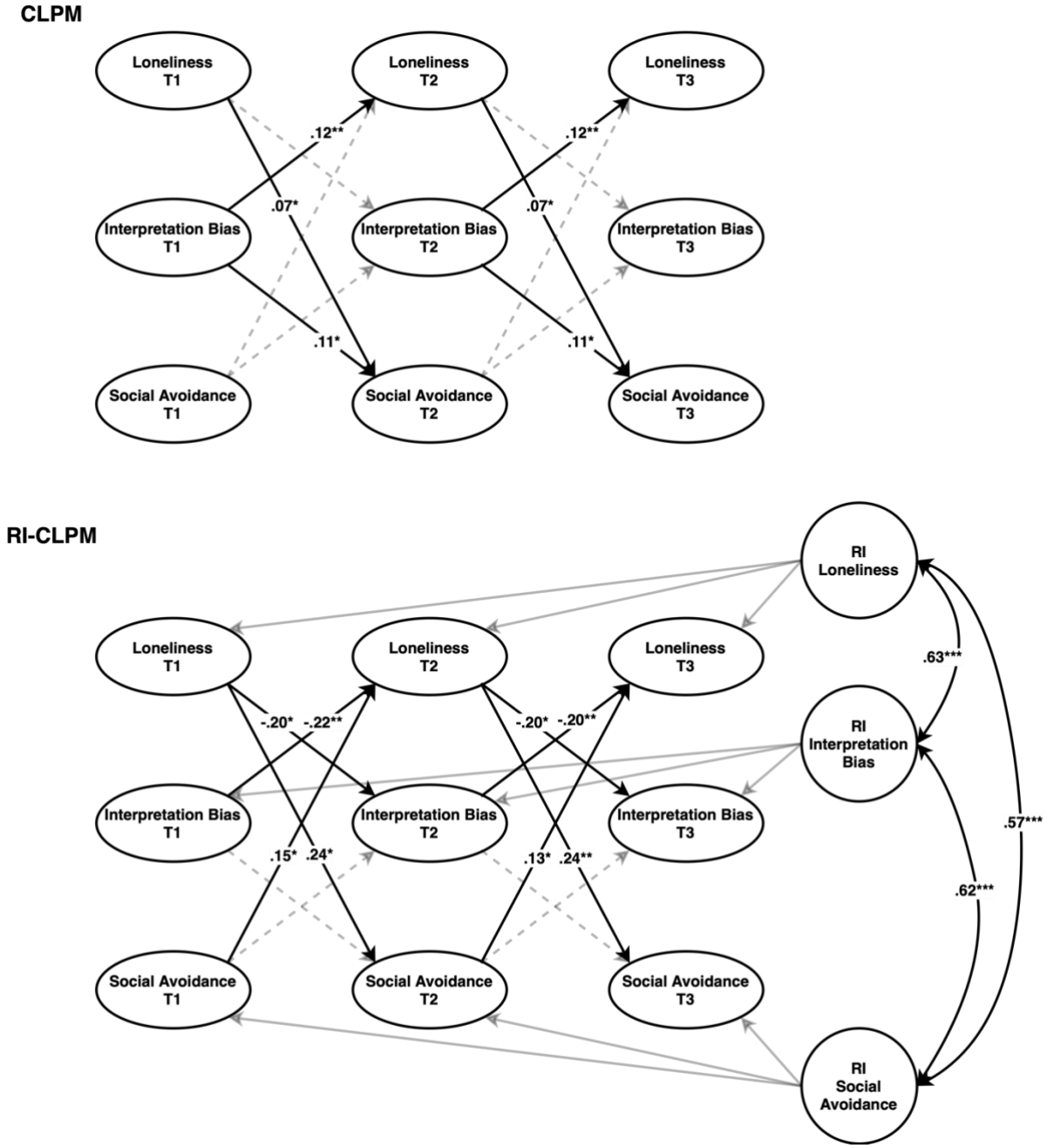
Summary of the CLPM and R-CLPM Correlations

	CLPM		*RI-CLPM*	
	r	*p*	*r*	*p*
Correlations of the Variables				
Loneliness and Interpretation Bias:				
L1 with IB1	**.57**	<.001	-.04	.677
L2 with IB2	.08	.715	-.08	.349
L3 with IB3	.09	.673	-.08	.324
Loneliness and Social Avoidance Behavior:				
L1 with SA1	**.55**	<.001	**.26**	.001
L2 with SA2	**.24**	.003	**.29**	<.001
L3 with SA3	**.36**	<.001	**.31**	<.001
Interpretation Bias and Social Avoidance Behavior:				
IB1 with SA1	**.66**	<.001	.13	.123
IB2 with SA2	**.54**	.046	.00	.977
IB3 with SA3	.30	.193	.00	.977
Correlations of the Random Intercepts				
Random Intercept L with Random Intercept IB	-	-	**.67**	<.001
Random Intercept L with Random Intercept SA	-	-	**.57**	<.001
Random Intercept IB with Random Intercept SA	-	-	**.65**	<.001

Note: L = loneliness, IB = interpretation bias, SA = social avoidance behavior, with numbers standing for the time points (T1, T2, T3). Standardized values are reported. SE refers to the standard error. Significant coefficients are in bold. *N* = 785.

Figure 1

Simplified Depiction of the CLPM and RI-CLPM with the Cross-Lagged Pathways



Note. The solid arrows refer to the significant cross-lagged pathways with their corresponding standardized coefficient. RI stands for Random Intercept. Stars indicate the level of statistical significance: * = $p < .05$, ** = $p < 0.01$, *** = $p < .001$ and dashed line for $p > .05$.

Appendix D: Article IV

Efficacy of an Internet-based self-help intervention with human guidance or automated messages to alleviate loneliness: A three-armed randomized controlled trial

Seewer, N., Skoko, A., Käll, A., Andersson, G., Luhmann, M., Berger, T., & Krieger, T. (2024). Efficacy of an Internet-based self-help intervention with human guidance or automated messages to alleviate loneliness: A three-armed randomized controlled trial. *Scientific Reports*. *14*(1), 6569. https://doi.org/10.1038/s41598-024-57254-0

Efficacy of an Internet-based Self-help Intervention with Human Guidance or Automated Messages to Alleviate Loneliness: A Three-Armed Randomized Controlled Trial

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ABSTRACT

Loneliness is a prevalent and stigmatized phenomenon associated with adverse (mental) health outcomes. However, evidence-based interventions to alleviate loneliness are scarce. This randomized controlled trial (ClinicalTrials.gov-ID: NCT04655196) evaluated the efficacy of an internet-based cognitive behavioral self-help intervention (ICBT) to reduce loneliness by comparing two intervention groups with guidance or automated messages against a waitlist control group. Adults (*N* = 243) suffering from loneliness were recruited from the general public and then randomly assigned (2:2:1) to a 10-week ICBT with human guidance (GU) or automated messages (AM) or to a waitlist control group (WL). Loneliness, assessed with the UCLA-9, was the primary outcome. Outcomes were assessed at baseline and 10 weeks (post) and analyzed using mixed-effects models. The pooled intervention conditions resulted in lower loneliness scores at post-assessment than the WL (Cohen's *d* = 0.57, 95%-CI [0.25; 0.89]) and reduced depressive symptoms, social anxiety, social avoidance behavior, and rejection sensitivity (*d* = 0.32-0.52). The GU group had lower loneliness scores at post-assessment than the AM group (*d* = 0.42, 95%-CI [0.13; 0.70]). ICBT effectively alleviated loneliness, and guidance increased the reduction in loneliness compared to automated messages. Alleviating loneliness with ICBT further seems to reduce the overall burden of psychopathological symptoms.

Introduction

Loneliness arises when fundamental needs for human connections are not met [1]. It can be defined as an aversive subjective experience resulting from a discrepancy between actual and desired social relationships in

terms of their quality and/or quantity [2]. One person can feel lonely despite being surrounded by people, while another person with a small social network may not. Thus, despite being related, loneliness and objective social isolation, i.e., lack of a social network, only show small correlations [3]. Albeit prevalence rates of loneliness have increased after the beginning of the COVID-19 pandemic [4], loneliness was even before a prevalent phenomenon. Between 2007-2012, in the German general population, around 10% reported feelings of loneliness [5], and a meta-analysis including studies from high-income countries published between 2008-2020 implies that around one in four of the older adult population feels lonely at least sometimes and 7.9% reported severe loneliness [6].

Loneliness seems not restricted to a specific age group but is prevalent across the lifespan [7-9]. Moreover, evidence suggests loneliness to be associated with adverse (mental) health outcomes, e.g., cardiovascular and brain health [10], depression [11], social anxiety [12], suicidal ideation and behavior [13], overall well-being [14], and an increased risk for early mortality, even after controlling for confounding variables such as depression [15,16]. Consequently, loneliness is increasingly recognized as a major public health concern [17]. Therefore, evidence-based interventions are needed to alleviate the individual and societal burden of chronic loneliness efficiently.

From an evolutionary perspective, loneliness is a driving force in maintaining existing and forming new social relationships to increase the chance of survival [18]. Thus, transient feelings of loneliness are a common and adaptive human experience. However, for some individuals, loneliness persists over a prolonged period and may have lost its adaptive characteristics [18]. A cognitive model of chronic loneliness [19,20] was proposed to describe the development and maintenance of chronic loneliness. It is assumed that feelings of loneliness trigger hypervigilance for potentially threatening stimuli in social situations leading to cognitive biases in social information processing, e.g., negative evaluation of the self and others. As a result, lonely people show behaviors, e.g., social withdrawal or passivity, that prevent them from gaining positive experiences in social situations. Because of this, feelings of loneliness persist through a self-perpetuating vicious cycle. Notably, negative associations with adverse health outcomes are predominantly reported in individuals experiencing chronic loneliness [21].

In line with a cognitive model of loneliness [20], previous meta-analyses have suggested that interventions aimed at changing maladaptive social cognitions are the most effective in reducing loneliness and promoting social connectedness [22,23]. Findings of a recent meta-analysis corroborated these results in showing the

efficacy of psychological interventions in alleviating loneliness, with cognitive behavioral interventions belonging to the most efficacious ways of reducing loneliness – however, not superior to other psychological interventions [24]. Hickin and colleagues [24] further stress the need for more high-quality studies on the efficacy of loneliness interventions.

Despite the availability of evidence-based treatments for various mental health problems, a treatment gap still hinders many people from accessing those treatments [25]. Technological advances have allowed psychological interventions to be delivered via the Internet and thus potentially reach more people needing treatment [26]. Evidence-based treatment manuals based on the face-to-face literature have often been adapted for the online setting and delivered as so-called Internet-based self-help programs. Many internet-delivered programs are based on cognitive behavioral therapy (CBT) principles and are often named ICBT. The interventions frequently consist of several modules that can be worked on independently by the users. ICBT has proven effective across multiple psychiatric and somatic disorders [26], and ICBT with guidance demonstrated comparable effectiveness to face-to-face therapies [27]. Due to the time and place-independent accessibility, scalability, and anonymity [26], Internet-based self-help interventions can reach more people in need of psychological treatment, especially those with (self-) stigmatized conditions such as loneliness [28].

Internet-based interventions to reduce loneliness have been developed and tested in initial studies and shown promising results [29,30]. In a pilot RCT, guided ICBT was compared to a waitlist control group [29]. Loneliness was significantly reduced after the intervention phase with a between-group effect size of $d = 0.77$. Further support for the efficacy of ICBT was reported in a three-armed trial comparing ICBT against an Internet-based Interpersonal Therapy intervention (IIPT) [30]. While loneliness was significantly reduced in participants in the ICBT condition compared to the waitlist control condition (Cohen's $d = 0.71$) and the IIPT condition (Cohen's $d = 0.53$) at post-assessment, no statistically significant difference was found between IIPT and the waitlist condition. While the findings of these studies highlight that loneliness can effectively be reduced with guided ICBT, the study designs do not allow controlling for the effects of guidance (i.e., weekly feedback by a therapist or coach). However, this could be relevant, especially in the context of loneliness, as human guidance could touch upon aspects relevant to satisfying social relationships (e.g., validation) and thus lead to a greater reduction in loneliness [29].

A further study examined an unguided Internet-based friendship enrichment program to reduce loneliness [31]. In this trial, only one third of the participants completed all modules [32]. Studies have found improved

treatment completion rates when an automated email message reminds patients to continue working on the treatment [33]. Furthermore, it has been shown that Internet-based interventions with human guidance can increase adherence to the intervention, i.e., raise the average amount of intervention completion (g = 0.29, 95% CI [0.18; 0.40]) [34] and lead to greater effects than unguided (human guidance: g = 0.63, 95% CI [0.50; 0.76]; unguided: g = 0.34, 95% CI [0.24; 0.45]) [35] or technologically guided interventions, i.e., automated messages (pooled effect size in favor of human guidance: g = 0.11, 95% CI [0.03; 0.19]) [36]. In a more recent meta-analysis, a higher degree of human contact was associated with a better treatment outcome after internet-based interventions for depression, i.e. contact before and during treatment: Standardized mean difference (SMD) = 0.57, 95% CI [0.44; 0.71] vs. contact before treatment only: SMD = 0.48, 95% CI [0.33; 0.63]) [37]. It is thus of relevance to further examine the effects of human guidance on the outcome of lonely.

The present study was designed to examine the effects of an ICBT program against loneliness. The ICBT program addressed aspects relevant to the cognitive model of loneliness described above (e.g., maladaptive social cognitions, avoidance behavior) to break the vicious cycle of loneliness (see methods section for a more detailed description of the ICBT program). In a three-armed randomized controlled trial (RCT), we compared ICBT with human guidance and ICBT with automated messages against a waitlist control group. Additionally, we compared the intervention groups against each other to investigate the added effect of human guidance. Our primary hypothesis was that participants in the pooled intervention conditions would show greater reductions in loneliness and secondary outcomes such as depressive symptoms, social anxiety symptoms, and cognitive bias compared to the waitlist control group. Additionally, we expected participants in the guided condition to show greater improvements regarding loneliness and more favorable results on the secondary outcomes than in the automated message condition.

Results

Baseline Comparisons and Preliminary Analyses

Table 1 shows the baseline characteristics of the full sample. There were no significant baseline differences between groups on any demographic and loneliness-specific variables, nor regarding psychopathology (all p's > .07). Supplementary Table S2 shows baseline values and differences between groups on the primary and secondary outcomes. Participants did not significantly differ on any measure (all p's > .26), except for the DDI

($F(2,239) = 3.38$, $p = .04$, $\eta^2 = 0.03$), with significantly higher scores in the GU compared to the AM condition ($p = .04$). Regarding loneliness, participants had a mean value of 7.56 ($SD = 2.14$) on the 3-item short form of the UCLA Loneliness Scale. This means that a total of 241 (99.2%) participants had higher scores than the norm sample from the German general population, with 164 (67.5%) participants presenting higher scores than 95% of the German general population [38].

[Table 1 about here]

Study Dropout Analysis

In total, 63 participants (25.9%; GU, $n = 28$; AM, $n = 33$; WL, $n = 2$) did not complete the questionnaires at post-assessment. Non-completers did not differ from completers regarding primary or secondary outcomes at baseline (all p's > .06), nor demographic variables (p's > .10), except for age, where non-completers were significantly younger, ($t(241) = -2.62$, $p = .009$) (see Supplementary Tables S3-S4). Additionally, non-completion rates significantly differed between study conditions, $\chi^2(2, n = 243) = 15.50$, $p < .001$, $V = 0.25$), with a higher number of non-completers in the intervention conditions compared to the WL (GU vs. WL: $\chi^2(1, n = 146) = 11.75$, $p < .001$, $V = 0.28$); AM vs. WL: $\chi^2(1, n = 145) = 15.63$, $p < .001$, $V = 0.33$).

Intervention Usage

Data on the use of SOLUS-D was not available for five (2.6%) participants, as one (0.5%) deleted their account, one (0.5%) was not able to access the intervention due to technical problems, and three (1.5%) had never logged into the program after randomization without indicating reasons. Nevertheless, these participants were included in the descriptive statistics regarding the intervention usage. In total, 42 (42.9%) participants in the GU and 39 (40.2%) in the AM condition accessed all nine modules during the intervention phase. A total of 84.7% ($n = 83$) in the GU condition accessed at least four modules (number of modules for minimal therapeutic contact) compared to 72.2% ($n = 70$) in the AM condition [1]. On average, participants in the GU condition accessed 6.77 ($SD = 2.62$, $Md = 8$) out of nine modules, while participants in the AM condition accessed 6.07 ($SD = 3.16$, $Md = 7$) modules. The two groups did not significantly differ in their mean number of modules accessed ($t(186) = -1.67$, $p = .10$). Participants in the GU condition spent on average 563.28 min

[1] Thanks to a reviewer's suggestion, we further conducted a chi-squared test to examine if the number of participants who accessed 4 or more modules differed between both intervention conditions. Despite a statistically significant chi-squared test, $\chi^2(1) = 4.53$, $p = .03$, $V = 0.15$), post-hoc analyses comparing residuals to a critical value yielded no significant results.

(*SD* = 543.86, *Md* = 451) in the program compared to the AM condition with an average time of 370.44 min (*SD* = 338.36, *Md* = 292), which indicates a significant difference ($t(193) = -2.97$, $p = .003$, $d = -0.43$).

Intervention Effects on Primary Outcome

Observed means for the primary outcome measure UCLA-9 for GU, AM, and WL at baseline, and 10 weeks are presented in Figure 1.

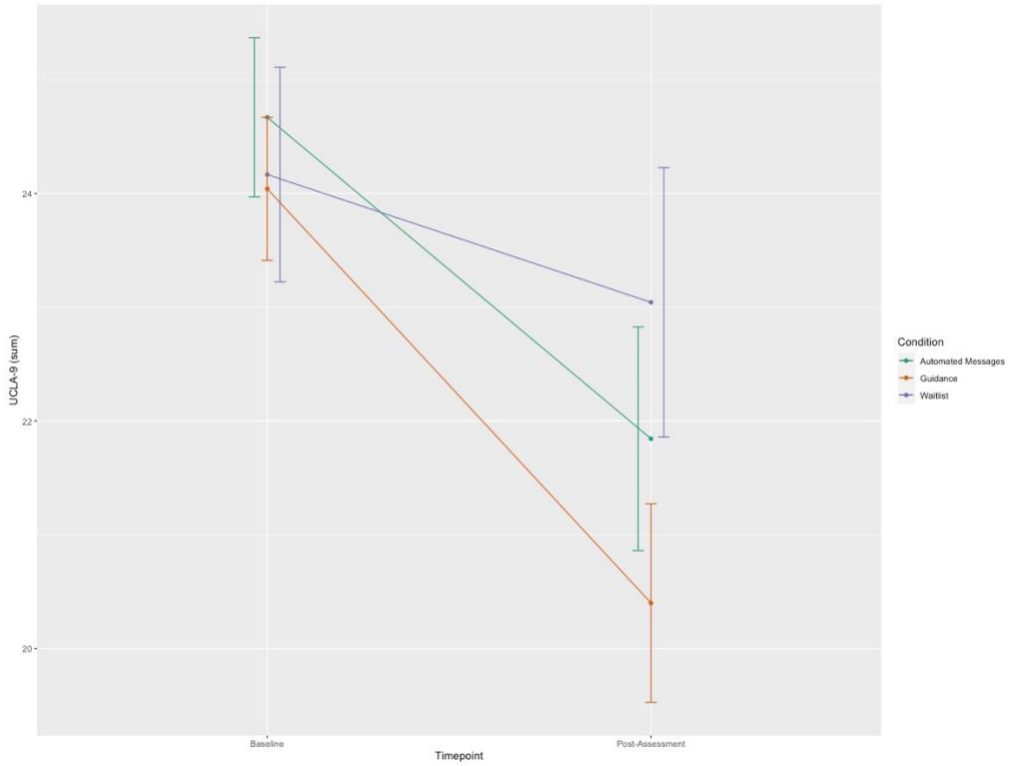

Figure 1. Observed means on the University of California Loneliness Scale – 9-item short form (UCLA-9) at all three time points with 95% confidence intervals.

Observed and estimated means on the primary outcome assessed at baseline and post-assessment are displayed in Table 2. Table 3 shows effect sizes for within- and between-group differences, overall effects, and contrasts for significant Time × Group interactions. Regarding the primary outcome, a linear mixed model showed a significant Time × Group interaction, $F(2, 191.98) = 8.22$, $p < .001$ (see Supplementary Table S5 for detailed results of the mixed effects model). Subsequent planned contrast analyses revealed significantly lower loneliness scores at post-assessment for the intervention conditions compared to the WL ($t(241) = 3.13$, $p <$

.002, d = 0.57, 95% CI [0.25;0.89]), with an additional significant difference between both intervention conditions in favor of the GU condition ($t(193) = 2.38$, $p = .02$, d = 0.42, 95% CI [0.13;0.70]) (see Supplementary Table S22 for a summary of the contrast analyses). Additionally, medium to large statistically significant within-group effects were found for the intervention groups (GU, d = 1.02, 95% CI [0.71;1.31]; AM, d = 0.73, 95% CI [0.43;1.02]) and a small, non-significant effect for the WL (d = 0.28, 95% CI [-0.12;0.68]).

[Table 2 about here]

[Table 3 about here]

Intervention Effects on Secondary Outcomes

In terms of secondary outcomes (see Table 2 and Table 3), significant Time × Group interactions were found for depressive symptoms, social anxiety symptoms, self-compassion, social avoidance behavior, misanthropy, and rejection sensitivity (p's = .001 to .05) (see Supplementary Tables S6-S21 for detailed results of the mixed effects models). Consecutive contrast analyses comparing both intervention groups to the waitlist control group showed significantly lower depressive symptoms (PHQ-9; $t(241) = 2.89$, $p = .004$, d = 0.52), social anxiety symptoms (SPS-6; $t(240) = 2.30$, $p = .02$, d = 0.37), social avoidance behavior (CBAS; $t(241) = 1.98$, $p = .048$, d = 0.32), and lower rejection sensitivity (A-RSQ; $t(240) = 2.22$, $p = .03$, d = 0.38) at post-assessment in favor of the intervention groups. See Supplementary Table S22 for a summary of the contrast analyses. For the other secondary outcomes with significant Time × Group interactions, i.e., self-compassion (SOCS-S), and misanthropy (BVI), contrast analyses comparing both intervention groups with the waitlist control group did not show significant differences at post-assessment (p's ranging from .09 to .18, d's ranging from 0.23 to 0.29). Contrast analyses comparing both intervention conditions against each other did not show significant differences at post-assessment on any secondary outcome (p's ranging from .05 to .92, d's from 0.02 to 0.31).

Focusing on change within groups, significant pre-post effects in the GU condition ranged from small to large (0.28 [SIAS-6] to 1.10 [Lonely_dir]) and were headed in the expected direction. No significant within-group effects were found regarding social anxiety symptoms (SPS-6), objective social isolation, satisfaction with life, social avoidance behavior, and misanthropy for the GU condition. For the AM condition, significant within-group effects ranged from small to large (0.28 [PID5BF+] to 0.92 [Lonely_dir]). Within this group, no significant pre-post effects were found for objective social isolation, self-compassion, social avoidance

behavior, misanthropy, authenticity, and motivation for solitude. The waitlist control condition did not improve significantly on any of the secondary measures, except for the single-item question assessing loneliness directly (d = 0.56; 95% CI [0.15;0.96]), corresponding to a reduction in loneliness.

Sensitivity Analyses

To explore the robustness of the results regarding the primary outcome, we conducted sensitivity analyses in the a) per-protocol sample and subgroups of participants, b) who fulfilled the criteria of at least one psychological disorder at baseline, or c) who were in concurrent psychotherapy at baseline. Observed and estimated means for the primary outcome assessed at baseline and post-assessment and effect sizes for within- and between-group differences are displayed in Supplementary Table S23. Furthermore, the mixed effects models are summarized in Supplementary Tables S25-S27. The same result pattern emerged for all three subgroups regarding the primary outcome when comparing the intervention groups with the control group. When comparing both intervention groups with each other, scenarios A and C revealed differences between GU and AM equivalent to the primary analyses. However, in scenario B, the difference between GU and AM at post-assessment was only borderline significant, (t(99) = 1.90, p = .06, d = 0.50) (see Supplementary Table S24 for a summary of the contrast analyses).

Reliable Improvement and Deterioration

Reliable improvement (pre-post change UCLA-9 > 2.93) in the ITT-sample (n = 243), did not significantly differ between GU (47/98, 48.0%), AM (40/97, 41.2%), and WL (15/48, 31.3%; χ^2(2) = 3.73, p = .15, V = 0.12). In terms of deterioration, a significant difference between GU (2/98, 2.0%), AM (5/97, 5.2%) and WL (6/48, 12.5%; χ^2(2) = 6.97, p = .03, V = 0.17) was observed. Participants in the GU condition had a significantly lower probability of deterioration in loneliness from pre to post compared to the WL condition (p = .02, OR = 0.15, 95%-CI: 0.02-0.73).

In the per-protocol sample (n = 172, i.e., participants who completed both baseline and post-assessment and accessed at least four modules) reliable improvement significantly differed between the three conditions (GU: 42/69, 60.9%; AM: 30/57, 52.6%; WL: 14/46, 30.4%; χ^2(2) = 10.46, p = .005, V = 0.25). Participants in the GU (p = .002, OR= 3.50, 95%-CI: 1.60-7.96) and in the AM condition (p = .03, OR= 2.51, 95%-CI: 1.12-5.82) had significantly higher probabilities for reliable improvement regarding loneliness than the participants in the WL condition. Concerning deterioration, a significant difference between conditions was observed (GU:

1/69, 1.4%; AM: 4/57, 7.0%; WL: 6/46, 13.4%; Fisher's Exact Test: $p = .04$). The probability for deterioration was significantly lower for participants in the GU ($p = .02$, OR = 0.11, 95%-CI: 0.00-0.71) compared to the WL condition.

Participant Satisfaction and Negative Effects

Regarding the satisfaction with the program (CSQ-8) assessed at post, participants in the GU ($n = 65$, $M = 3.18$, $SD = 0.61$) and AM condition ($n = 60$, $M = 3.02$, $SD = 0.55$) indicated to be generally satisfied with the treatment they received. The two groups did not significantly differ regarding their satisfaction with the program ($t(123) = -1.59$, $p = .12$). Both intervention groups rated the usability of the program as "good" [39], and there were no significant differences between the conditions (GU: $n = 66$, $M = 80.17$, $SD = 15.68$; AM: $n = 60$, $M = 79.44$, $SD = 16.02$; $t(124) = -0.26$, $p = .80$).

Due to a programming error, data regarding negative effects of eight participants in the GU and four participants in the AM condition could not be included in the analyses. Negative effects at post-assessment were computed for the completer sample. At post-assessment, participants in the GU ($n = 62$, $M = 0.32$, $SD = 0.81$) and AM condition ($n = 60$, $M = 0.35$, $SD = 0.88$) did not significantly differ concerning the mean number of reported negative effects due to the program ($t(120) = 0.18$, $p = .86$). A total of 13 (21.0%) participants in the GU and 15 (25.0%) in the AM condition did report at least one negative effect that they attributed to the self-help program. The number of negative effects reported ranged from 0-5 in the GU and 0-6 in the AM condition. Most frequently, participants (GU: $n = 9$, 14.5%, AM: $n = 6$, 10.0%) reported having experienced prolonged periods during the intervention phase when they felt bad (item 13). The second most mentioned was that they would suffer more from events from the past (GU: $n = 5$, 8.1%, AM: $n = 3$, 5.0%).

Discussion

The current study evaluated the effects of a 10-week Internet-based self-help intervention with human guidance or automated messages compared to a waitlist control group for people suffering from loneliness. At post-assessment, the pooled intervention groups showed significantly reduced loneliness compared to the control group. This finding was robust across several sensitivity analyses. Moreover, this study shows the superiority of human guidance versus automated messages in ICBT against loneliness for the first time. Regarding the secondary outcomes, the intervention groups showed reduced depressive symptoms, social

anxiety symptoms, social avoidance behavior, and rejection sensitivity at post-assessment compared to the waitlist control group. However, no significant differences in secondary outcomes at post-assessment were observed between the intervention groups. Satisfaction with the intervention was generally high and usability was rated as good in both intervention conditions, but no significant differences between intervention conditions were observed.

The greater decrease in loneliness in both intervention groups was according to our hypothesis, and further supports initial findings from Swedish trials on the efficacy of ICBT for reducing loneliness. The Swedish trials found moderate effects sizes (d = 0.77 [29] and d = 0.71 [30]) in favor of the guided ICBT compared to the waitlist control group, which is comparable to the current study with a moderate between-group effect size for the pooled intervention vs. WL condition (d = 0.57, 95% CI [0.25;0.89]) and a large effect size when comparing the guided ICBT with the WL (d = -0.80, 95% CI [-1.16; -0.44]). Thus, the results of the current study indicate that loneliness can be reduced with ICBT.

As hypothesized, the guided condition was superior to the automated message condition (d = -0.42, 95% CI [-0.70;-0.13]). This finding provides evidence for the first time on the role of human contact (i.e., guidance) in loneliness reduction with ICBT. It is possible that participants in the guided condition experienced aspects relevant to satisfying social relationships (e.g., being valued and understood by the coaches), which directly led to a more substantial reduction in loneliness. However, they might also have felt accountable to the coach and thus used the self-help program more intensively and thoroughly, leading indirectly to a reduction in loneliness. The latter might be reflected in the time spent within the program, which was significantly higher in the guided than in the automated message condition. This aligns with previous studies highlighting increased adherence in guided versus automated message/unguided conditions for various mental health interventions [34]. A recent study in people suffering from depressive symptom further showed that both therapeutic alliance and adherence mediated the effect of guidance [40]. However, in the aforementioned studies, adherence was operationalized as the completion rate of modules [34] or as a composite score consisting of number of clicks, number of topics worked on, number of completed exercises, and time spent within the program [40], respectively. The number of modules accessed yielded non-significant differences between study groups in the current study. This points to the relevance of carefully considering the operationalization of adherence and adds to the ongoing discussion on how to conceptualize best and assess adherence in internet-based interventions [41]. Overall, investigating the direct and indirect effects of guidance on the reduction of loneliness merits further investigation.

Loneliness was assessed by different means in the current trial. An indirect measure of loneliness (i.e., without mentioning “lonely”) was administered as the primary outcome. Furthermore, we directly asked the participants how often they felt lonely. While a significant difference at post-assessment on the indirect measure of loneliness was found between the intervention and waitlist control conditions, no difference between groups was observed in the direct assessment of loneliness. The significant reduction in the direct measure of loneliness within all three study conditions may have contributed to the absence of group differences at post. Accordingly, the choice of measure for loneliness could be of relevance in intervention research. Prior research [42] already highlighted diverging results, e.g., regarding the prevalence of loneliness if measured directly or indirectly. Therefore, a better understanding of the constructs captured with indirect and direct measures of loneliness is needed.

Concerning secondary outcomes, the intervention groups showed significantly reduced depressive symptoms at post-assessment compared to the control group. A decrease in depressive symptoms has also been reported for the ICBT condition compared to the control group in the study by Käll and colleagues [30]. Furthermore, in line with another trial [29], we found a significant reduction in social anxiety symptoms in the intervention groups compared to the waitlist. Findings of previous observational studies [11,12,43] point to the interrelatedness between loneliness, depression, and social anxiety. Decreasing loneliness might thus relate to changes in social anxiety and depression. However, further research is needed to clarify whether the intervention for loneliness directly affects symptoms of anxiety and depression or if changes in loneliness influence those symptoms. This would shed light on the relationship between loneliness and social anxiety and depression and, furthermore, allow to improve interventions for lonely individuals with comorbid social anxiety or depression.

Regarding further secondary outcomes, the intervention groups showed reduced social avoidance behavior and rejection sensitivity at post-assessment compared to the waitlist control group. Concerning other secondary outcomes associated with the cognitive model of loneliness (e.g., interpretation bias), comparing the intervention conditions to the control group and both intervention groups with each other did not show significant differences at post-assessment. Since loneliness is a complex phenomenon, it is possible that changes in secondary outcomes have taken place at the individual level but are not reflected at the group level. Possible sources of the complexity of loneliness are the various causes that can lead to loneliness, e.g., the death of a close relative, a small social network, or feelings of personal inadequacy [44]. Depending on the underlying causes and individual circumstances, taking different approaches to break the vicious cycle of loneliness might be necessary [45]. A person with a small social network may need different strategies to reduce

their loneliness than someone with a larger social network. A better understanding of the causes, circumstances, and characteristics of lonely individuals would allow tailoring interventions to the needs of those individuals.

It is also noteworthy that loneliness was reduced in the intervention groups, although there was no change in the size of the social network at the mean level. This supports the current literature indicating that the attitude towards oneself and the quality of social relationships may be more relevant to feelings of loneliness than the number of social relationships. Thus, interventions aiming solely at increasing social contact might not reduce feelings of loneliness [23]. Furthermore, despite the significant mean change in loneliness in favor of the intervention groups, it also became evident that some participants profited more from the respective intervention than others. Almost half of the participants in the guided and about 40% in the automated messages condition showed a reliable improvement at post-assessment. Accordingly, the object of future research should be to identify predictors and moderators of a reduction in loneliness. This would help to better understand for whom ICBT to alleviate loneliness would be suitable or who would benefit from additional human guidance.

The results of the present study should be considered in the light of several limitations. First, we excluded participants presenting severe depressive symptoms at baseline, preventing us from generalizing our results to lonely individuals with severe depressive symptoms. Second, we investigated a self-selected sample, which might imply that only individuals highly motivated to use an Internet-based self-help intervention participated in the study. Our results thus mainly apply to individuals motivated to work on their feelings of loneliness using an Internet-based self-help intervention. Third, our sample was predominantly female and highly educated. Thus, it did not represent the entire bandwidth of individuals experiencing loneliness. However, almost 70% of the sample showed higher baseline loneliness scores than 95% of the German general population, implying that we recruited a highly burdened subsample of lonely individuals. Fourth, the present results only allow us to conclude the short-term effects of the intervention. However, participants in both intervention conditions completed questionnaires 6 and 12 months after randomization, and the results of follow-up assessments will be disseminated later. Finally, since self-report measures were used for data collection, it cannot be ruled out that people may have given socially desirable answers, and thus the data may have been biased. However, since loneliness is a purely subjective feeling, self-report measures on loneliness are essential.

In conclusion, the present study demonstrated that an Internet-based self-help intervention mainly based on CBT principles effectively reduces loneliness. The findings add to the existing evidence on the efficacy of ICBT in reducing loneliness, and they advance existing knowledge by showing that compared to automated messages, human support is associated with lower loneliness scores after the intervention. Since the Internet-based self-help intervention not only reduced loneliness but also decreased depressive and social anxiety symptoms, alleviating loneliness using ICBT might thus also contribute to the reduction of the overall burden of mental health disorders.

Methods

Study Design

We conducted a 10-week randomized controlled trial (RCT) using a parallel-group design, comparing two active intervention conditions to a waitlist control condition (see Fig. 2). Both intervention conditions had immediate access to the self-help program, and participants in the waitlist control group were given full access ten weeks after randomization.

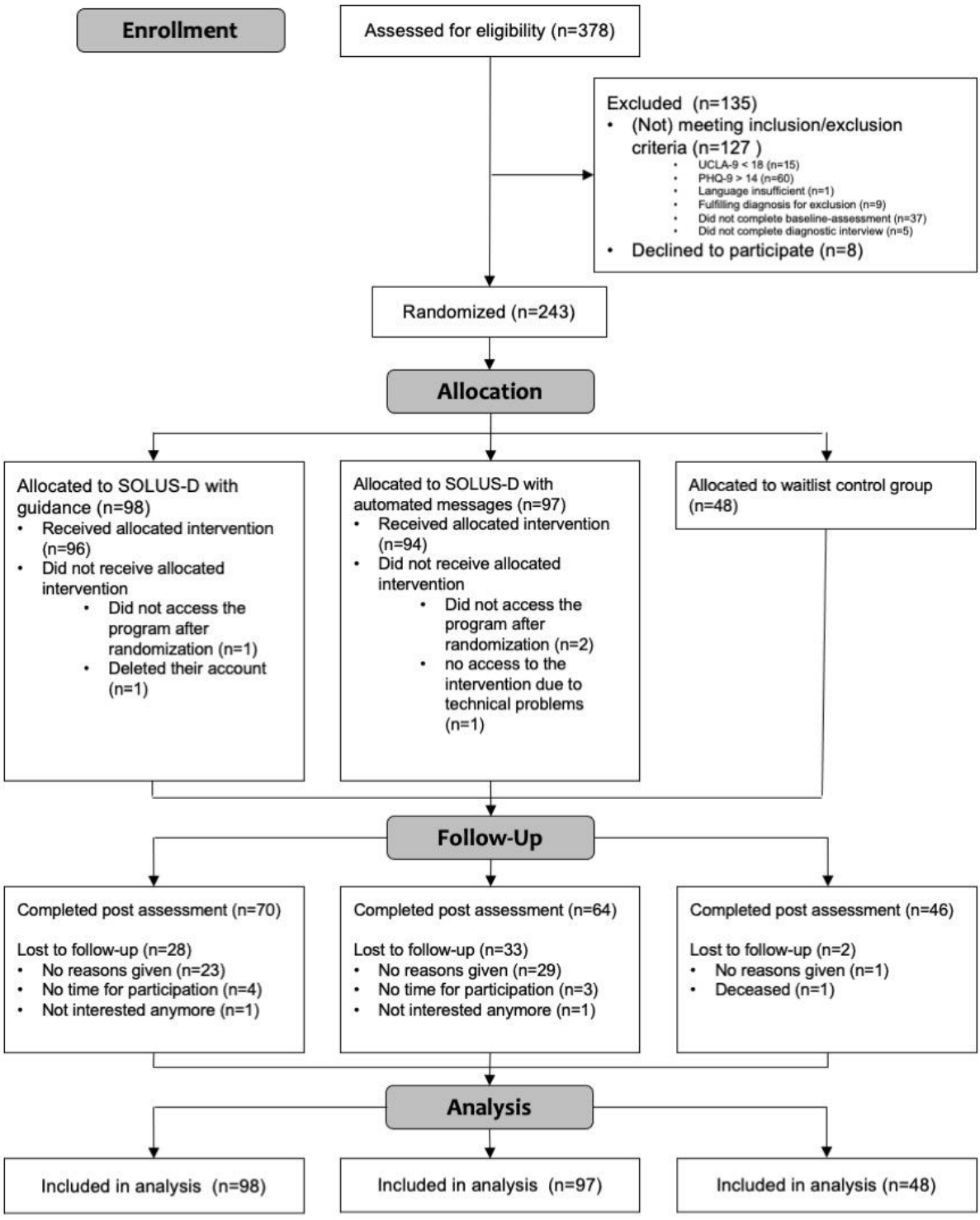

Figure 2. CONSORT (Consolidated Standards of Reporting Trials) diagram. Post = week 10 assessment.

This trial was conducted and reported following the CONSORT-SPI 2018 checklist [46]. This trial was preregistered with clinicaltrials.gov (NCT04655196, registration date: 07/12/2020), conducted in accordance with the declaration of Helsinki, and has been approved by the Cantonal Ethics Committee Bern (CEC; ID:

202-01298). Moreover, we published a study protocol [47]. Informed consent was obtained from all subjects before participating in the study.

Participants and Procedure

To be included in the study, individuals had to be at least 18 years old, score 18 or higher on the UCLA Loneliness Scale – 9 item version (UCLA-9), have sufficient knowledge of German, have access to the Internet and an Internet-enabled device, and provide a signed consent form and a contact person in case of emergency. Individuals with current severe depressive symptoms, a lifetime diagnosis of psychotic or bipolar disorder, fulfilling the criteria for a current severe substance use disorder, or reporting acute suicidal plans were excluded from the study. Depressive symptoms were assessed with the PHQ-9, and the other exclusion criteria were evaluated with the diagnostic interview [Mini-DIPS-Open Access; 48]. All study participants were allowed to use additional therapeutic services and medication.

Between May 17, 2021, and July 31, 2022, we recruited 243 participants from the general population in German-speaking countries. Participants were recruited via social media, articles/interviews in newspapers, radio interviews, newsletters, google-ads, the study website, and the website listing ongoing studies from our research hub. After registering on the study website and returning a signed informed consent via email or post, interested participants received an email link to the baseline assessment. Trained and supervised master- and doctoral students conducted diagnostic interviews [Mini-DIPS-Open Access; 48] via telephone with all participants who completed the baseline assessment to assess diagnoses relevant to exclusion from the study. After the diagnostic interview, eligible participants were automatically block-wise randomized with Qualtrics [49] to either the two intervention conditions (Internet-based self-help program with human guidance or automated messages) or the waitlist control group. After the group allocation, participants in the intervention conditions had access to all modules of the Internet-based self-help program. In addition to the baseline assessment, all participants were asked to complete further assessments at 10 weeks (post) after the randomization. After completing the post-assessment, the waitlist control group received access to the intervention in a self-guided format. After randomization, participants and coaches delivering guidance were not blinded concerning the corresponding group allocation. Participants were not compensated for partaking in the trial. There was no face-to-face contact between participants and the study team, throughout the study period. All communication took place via email, telephone, or via the message function within the self-help platform.

Out of 378 potential participants, 243 met all inclusion and no exclusion criteria and were eligible to participate. In total, 98 participants were randomly assigned to the guidance condition, 97 to the automated message condition, and 48 to the waitlist condition (see Fig. 2). Socio-demographics are reported in Table 1. The sample was mainly female (*n* =191, 78.6%), living alone (*n* = 153, 63.0%), single (*n* = 182, 74.9%), and had a university degree (*n* = 151, 62.4%). Participants were between 19 and 80, with a mean age of 45.77 (*SD* = 14.85) years. A total of 79 (32.5%) were in psychological treatment at baseline, and 125 (51.4%) fulfilled the criteria of at least one psychological disorder according to the diagnostic interview (Mini-DIPS OA). The most prevalent was social anxiety disorder (*n* = 71, 29.2%). On average, participants experienced loneliness for 11.62 years (*n* = 238, *SD* = 13.91, *Md* = 5.25).

Intervention – SOLUS-D

SOLUS-D. The Internet-based self-help program SOLUS-D is a German adapted version of an Internet-based self-help program developed and pilot-tested in Sweden [29]. The program content is mainly based on cognitive behavioral principles. Compared to the original version, SOLUS-D contains additional modules focusing on mindfulness, self-compassion, and social skills relevant to building or deepening social relationships. SOLUS-D consists of nine modules that are mainly text-based and contain video and audio elements. Each module delivers theoretical information with a specific thematic focus, whereby this content can be deepened and transferred to everyday life with practical exercises. An integrated diary function was additionally aimed at changing the attentional focus and becoming more aware of compassion for the self and others in everyday life. A detailed description of the program content can be found in Supplementary Table S1. We recommended working on one module per week, corresponding to an approximate weekly time commitment of 50 minutes. However, participants could spend more time on the modules, corresponding exercises, and diaries. As the modules build on each other, we recommended working on them in a specific sequence. However, as the order of the program content might not suit everyone, all modules were unlocked from the beginning rather than every week. Participants were free to repeat content and exercises upon their preferences. The program was accessible by computer, smartphone, or tablet. Secure Socket Layer encryption was used to secure Internet-based communication with the program and the guides. Within the program, participants were only identifiable with anonymous login names, and they had a personal, password-protected login for the program.

Study Conditions

Participants in the "*Guidance*"- condition (GU) had access to SOLUS-D one day after randomization. They received weekly individualized feedback (i.e., guidance) from trained and supervised coaches through the message function of the self-help program. Participants were informed via the study information and after group allocation that a coach sent the weekly messages. The messages entailed feedback on participants' work within the program during the previous week and answered individual questions. An example of a weekly guidance message can be found in the online Supplementary Material. The primary aim of the guidance was to motivate participants to continue with the program. The main content of the messages was semi-structured and manualized according to the theoretical model of Supportive Accountability [50]. This model aims to increase adherence through human contact by being accountable to a coach. The coaches sent participants who did not log into the program in the previous week a standardized reminder. Reminders were sent for up to three consecutive weeks if participants did not log into the program or react to the reminders. The coaches were two psychologists with a master's degree in their first year of a CBT post-graduate program and ten master's students in their last term of a graduate program in clinical psychology. The authors NS, AS, and TK trained and supervised the coaches. On average, the coaches spent 17.10 minutes (SD = 10.15, Md = 14.25) on guidance per participant per week.

Participants in the "*Automated Message*"-condition (AM) had access to SOLUS-D one day after randomization and received weekly standardized messages via email. Participants were informed via the study information and after group allocation that the weekly messages were sent automatically and not by a study team member, i.e., a human being. The automated messages aimed to motivate participants to continue working with the program, e.g., by summarizing the module contents of the previous week and providing an outlook of the next module. An example of a weekly automated message can be found in the online Supplementary Material. After receiving access to the intervention, participants in the AM conditions were informed that upcoming technical problems could be addressed to the study team.

Participants in the "*Waitlist Control Group*" (WL) received access to the intervention in a unguided format, i.e., without guidance or automated messages, ten weeks after randomization upon completing the post-assessment. After receiving access to the intervention, participants in the WL condition were informed that upcoming technical problems or questions regarding the program could be addressed to the study team.

Measures

Demographic variables (e.g., gender, age, and education level) and therapy and medication status were self-reported by the participants at baseline. Self-reported primary and secondary outcome measures were assessed at baseline, and 10 weeks after randomization. Participants who did not respond to the assessment invitation received up to three weekly reminders via email. All questionnaires were administered in German and completed on the online survey platform Qualtrics [49] by the participants. The diagnostic interview was administered via telephone.

Primary Outcome

Loneliness, measured at the post-assessment timepoint, was the primary outcome and was assessed with the 9-item short version (UCLA-9) [51] of the UCLA Loneliness Scale [52,53]. The original scale consists of 20 Items and assesses three dimensions of loneliness: intimate, relational, and collective. The nine-item version consists of the three items with the highest factor loadings on each facet of loneliness [54]. The validity and reliability of the short version are comparable with those of the 20-item original scale [55]. The response options are (1) never, (2) rarely, (3) sometimes, and (4) always. After recoding reverse-coded items, all items are summed up, and the total score ranges from 9 to 36, with higher values indicating more pronounced feelings of loneliness. Cronbach's α for the UCLA-9 at post-assessment was 0.83. Internal consistency at post-assessment is reported since baseline data were affected by range restriction and biased reliability since we used the UCLA-9 as an inclusion criterion [56]. As previous studies detected differences, e.g., in the prevalence of loneliness, depending on either directly (i.e., using the word "lonely") or indirectly (i.e., not mentioning the word "lonely") measuring loneliness [42], an additional single item was administered to assess *loneliness directly*. Furthermore, an additional 3-item short form of the UCLA Loneliness Scale (UCLA-3) [57] was used, as norms for the German population exist [38].

Secondary Outcomes

Depressive symptoms were assessed with the 9-item depression module of the Patient Health Questionnaire (PHQ-9) [58,59]. The short form of the Social Interaction Anxiety and Social Phobia Scale (SIAS-6 & SPS-6) [60] was used to assess symptoms of *social anxiety*. *Satisfaction with life* was measured with the 5-item Satisfaction with Life Scale (SWLS) [61,62]. Furthermore, we assessed *self-esteem* with the 10-item revised German version [63] of the Rosenberg Self-Esteem Scale (RSES) [64] and used the 20-item Sussex-Oxford Compassion for the Self Scale (SOCS-S) [65] to measure *self-compassion*. The Social Network Index (SNI) [66] was administered to assess *objective social isolation*, i.e., network size [67]. We used the Personality Inventory for the DSM-5 Brief Form Plus (PID5BF+) [68] to assess *maladaptive personality traits*. *Interpretation bias*

was assessed with the respective subscale of the Interpretation and Judgmental Bias Questionnaire (IJQ) [69,70]. The Adult-Rejection Sensitivity Questionnaire (A-RSQ) [71] was used to measure *rejection sensitivity*. Furthermore, we administered the subscale Behavior-social avoidance of the Cognitive-Behavioral Avoidance Scale (CBAS) [72,73] to assess *social avoidance behavior.* The Distress Disclosure Index (DDI) [74] measured *comfort with self-disclosure*. We administered the Kernis Goldman Authenticity Inventory - short form (KGAI-SF) [75] to assess *authenticity*. We used the corresponding subscale of the Bern Embitterment Inventory (BVI) [76] to assess *misanthropy*. *Self-determined motivation for solitude* was assessed with the respective subscale from the Motivation for Solitude Scale – Short Form (MSS-SF) [77].

Further measures

At post-assessment, participants in both intervention groups completed measures on *client satisfaction* (CSQ-8) [78] and *usability* (SUS) [39] of the intervention. Moreover, we assessed *negative effects* that occurred during the intervention phase and were attributed to the intervention by participants in the intervention conditions with the INEP [79] at post-assessment. *Adherence* to the Internet-based program was assessed as the number of modules completed. A module was considered completed when each page per module had been clicked at least once. Furthermore, the time participants spent within the program was measured. The coaches noted down the amount of time they spent reading the participants' content within the program, as well as writing and delivering guidance. Before randomization, we administered the Mini-DIPS-Open Access [48] to assess *diagnoses of mental disorders.* We refer to the online Supplementary Material and the study protocol [47] for a more detailed description of all measures.

Statistical Analyses

Following the intention-to-treat principle (ITT), we included all randomized participants in the primary analyses. We computed ANOVAs for continuous and Chi-Square tests for nominal data to assess group differences at baseline and group comparisons regarding reliable change. Independent sample t-tests were performed to determine group differences in program usage, satisfaction with the program, and negative effects due to the intervention. Where relevant assumptions for the respective tests were violated, we conducted non-parametric tests, e.g., Fisher's Exact Test or Kruskal-Wallis Test. For the primary analyses, we used linear mixed models with restricted information maximum likelihood estimation in the *lme4* package [80] in R (version 4.2.1) to evaluate change in the primary and secondary outcome variables. Linear mixed models

are suitable for longitudinal data with repeated measures, as the dependency of the data is accounted for [81]. Furthermore, linear mixed models yield robust estimates despite missing data, accounting for it through maximum likelihood estimation, which produces unbiased estimates under the Missing at Random (MAR) assumption [82]. We estimated linear mixed models for the primary and each secondary outcome separately with fixed effects of time, condition, Time × Group interaction, and random intercepts for participants to evaluate the efficacy of the intervention. Time and condition were entered into the models as categorical variables. We did not include random slopes as the convergence of the model could not be achieved. Significant Time × Group interactions were followed up with planned contrast analyses, where we compared the two intervention conditions against the waitlist condition (GU: -0.5, AM = -0.5, WL = 1) and the two intervention conditions against each other (GU: -1, AM = 1, WL = 0). Following Feingold [83], between-group effect sizes (i.e., Cohen's *d*) were calculated by dividing the estimated mean difference at post-assessment by the pooled standard deviation at baseline. Within-group effect sizes were calculated by dividing the difference between the estimated means (pre-post) by the pooled standard deviation of the observed means from both time points. Additionally, we estimated 95% confidence intervals for the effect sizes. The α error level was set to .05. Only the primary outcome measure and the PHQ-9 required participants to answer all items. This was not the case for the other questionnaires to reduce the attrition rate. Accordingly, for scales with missing values at the item level, the scale scores were calculated with the available data [84].

Reliable improvement or deterioration in the primary outcome was calculated using the reliable change index (RCI) [85]. To determine the reliable change index, we used Cronbach's alpha (.90) of the UCLA-9 from a sample of the general population of German-speaking countries (n = 813, unpublished data) and the current study samples' standard deviation at baseline (SD = 3.34). Participants with change scores (pre-post) greater than 2.93 on the UCLA-9 were classified as reliably improved, not changed when scoring between 2.93 and -2.93, and deteriorated with a change score lower than -2.93. To ensure a conservative estimate of the change in loneliness, reliable change was computed using the ITT sample, replacing missing values at post-assessment with the last observation carried forward. Additionally, reliable change was calculated in the per-protocol sample consisting of participants who completed the baseline- and post-assessment and logged into four or more modules (i.e., minimal therapeutic contact).

High dropout rates in studies on Internet-based self-help programs are common and can lead to biased results. To check the robustness of the results, we additionally conducted sensitivity analyses and ran the primary analyses with the per-protocol sample. We conducted further sensitivity analyses focusing on different

subgroups, i.e., participants fulfilling at least one psychological disorder and participants indicating to attend psychotherapeutic treatment at baseline.

Sample Size and Power

We conducted an a priori power analysis using G*Power 3 [86] and aimed at detecting small effect sizes [87] of f = .10 (equivalent to Cohen d = 0.20) for the Time × Group interaction for the two intervention conditions at an α error level of .05., a power (1-β) of 0.80, and with correlations of r = .60 between pre-and post-treatment measures, as found in a previously conducted trial on ICBT for loneliness [29]. According to the power analysis, a sample size of 80 participants per intervention group was sufficient to detect statistically significant differences with these assumptions. Furthermore, to account for dropouts of approximately 25%, we decided to randomize 100 participants to each intervention group. Concerning the comparison between the intervention and waitlist control groups, 50 participants were considered sufficient for the waitlist since between-group effects were expected to be medium-to-large, based on the Swedish trials mentioned above [29,30]. Thus, we intended to randomize 250 participants (randomization ratio: 2:2:1). For regulatory reasons, we had to end recruitment when 243 participants were randomized, which might have limited our ability to detect the intended effects.

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Author contributions statement

T.K., T.B. and G.A. designed the trial, and T.K. received funding for this trial. A.K. and G.A. provided the Swedish version of the internet-based self-help program. N.S., A.S., and T.K. designed and extended the German version of the internet-based self-help program. N.S., A.S., and T.K. conducted the study. N.S. analyzed the results. N.S. and T.K. wrote the first draft of the manuscript. A.S., A.K., G.A., T.B., and M.L. critically proofread the manuscript and provided valuable inputs for adjustment. All authors contributed to the final version of the manuscript.

Ethics declarations

Competing interests

The authors declare no competing interests regarding the publication of this paper.

Additional information

Data Availability

De-identified data and statistical codes supporting the findings of this study will be made available upon publication of the manuscript on OSF (https://osf.io/tmk5e/). Information on demographics and diagnoses is not included in this data set to ensure the privacy of participants.

Online Supplementary Material

Online Supplementary Material is available and contains further information on the methods and results sections.

Table 1. Baseline Characteristics ITT-sample.

	GU (*n* = 98)	AM (*n* = 97)	WL (*n* = 48)	Statistic
Mean age, years (SD)	46.2 (15.5)	45.6 (14.7)	45.2 (14.1)	F (2,240) = 0.09; p = .92
Gender, n (%)				$\chi^2(4) = 1.91$; p = .75
Female	76 (77.6%)	77 (79.4%)	38 (79.2%)	
Male	21 (21.4%)	20 (20.6%)	9 (18.8%)	
Other	1 (1.0%)	0 (0.0%)	1 (2.1%)	
Marital status n (%)				$\chi^2(2) = 2.11$; p = .35
Single/divorced/widowed	72 (73.5%)	77 (79.4%)	33 (68.8%)	
Married/partnered	26 (26.5%)	20 (20.6%)	15 (31.2%)	
Living situation, *n* (%)				$\chi^2(6) = 5.57$; p = .47
Alone	66 (67.3%)	63 (64.9%)	24 (50.0%)	
With partner/family	17 (17.3%)	20 (20.6%)	12 (25.0%)	
Shared flat	10 (10.2%)	10 (10.3%)	7 (14.6%)	
Other	5 (5.1%)	4 (4.1%)	5 (10.4%)	
Highest educational level, *n* (%)				$\chi^2(4) = 4.36$; p = .36
Middle school	4 (4.1%)	0 (0.0%)	1 (2.1%)	
High school/some college	32 (33.0%)	37 (38.1%)	17 (35.4%)	
University degree	61 (62.9%)	60 (61.9%)	30 (62.5%)	
Employment, *n* (%)				$\chi^2(10) = 17.23$; p = .07
Full-time paid work	32 (32.7%)	32 (33.7%)	16 (34.0%)	
Part-time paid work	28 (28.6%)	27 (28.4%)	17 (36.2%)	
Student/in training	7 (7.1%)	5 (5.3%)	3 (6.4%)	
unemployed	3 (3.1%)	12 (12.6%)	3 (6.4%)	
Househusband/Housewife	2 (2.0%)	2 (2.1%)	4 (8.5%)	
Retired	26 (26.5%)	17 (17.9%)	4 (8.5%)	
Current psychological treatment [a]	31 (31.6%)	33 (34.0%)	15 (31.3%)	$\chi^2(2) = 0.17$; p = .92
Current use of psychotropic medication [a]	13 (13.3%)	17 (17.5%)	10 (20.8%)	$\chi^2(2) = 1.48$; p = .48
Mean duration of loneliness, months (*SD*)[b]	128.42 (153.60)	117.38 (137.55)	206.17 (224.05)	*Kruskal-Wallis* $\chi^2(2) = 4.89$; p = .09
Psychiatric diagnoses [c]				
Major depressive disorder	9 (9.2%)	13 (13.4%)	5 (10.4%)	$\chi^2(2) = 0.91$; p = *.64*
Panic disorder	5 (5.1%)	7 (7.2%)	5 (10.4%)	$\chi^2(2) = 1.41$; p = *.49*
Agoraphobia	2 (2.0%)	7 (7.2%)	5 (10.4%)	$\chi^2(2) = 4.79$; p = *.09*
Social anxiety disorder	25 (25.5%)	29 (29.9%)	17 (35.4%)	$\chi^2(2) = 1.56$; p = *.45*
Generalized anxiety disorder	17 (17.3%)	14 (14.4%)	7 (14.6%)	$\chi^2(2) = 0.36$; p = *.83*
Obsessive compulsive disorder	3 (3.1%)	4 (4.1%)	1 (2.1%)	$\chi^2(2) = 0.48$; p = *.80*
Post-traumatic Stress Disorder	2 (2.0%)	5 (5.2%)	3 (6.3%)	$\chi^2(2) = 1.89$; p = *.39*
Eating disorder	4 (4.1%)	2 (2.1%)	1 (2.1%)	$\chi^2(2) = 0.85$; p = *.65*

Note. GU = SOLUS-D with guidance; AM = SOLUS-D with automated message; WL = waitlist control group.
[a] Reflects the number and percentage of participants answering "yes" to this question.
[b] GU: n = 97; AM: n = 94; WL: n = 47
[c] Reflects the number and percentage of participants fulfilling the respective psychological diagnosis as indicated by the Mini-DIPS during screening.

Table 2. Observed and estimated means for primary and secondary outcome measures.

Measure	Condition	Baseline		Post (observed)		Post (estimated)	
		Mean (*SD*)	*n*	Mean (*SD*)	*n*	Mean (*SE*)	*n*
UCLA-9	GU	24.04 (3.18)	98	20.40 (3.73)	70	20.53 (0.41)	98
	AM	24.67 (3.51)	97	21.84 (4.01)	64	21.93 (0.42)	97
	WL	24.17 (3.33)	48	23.04 (4.10)	46	23.12 (0.53)	48
PHQ-9	GU	8.90 (3.35)	98	6.12 (3.11)	69	6.00 (0.41)	98
	AM	8.87 (3.31)	97	6.67 (3.31)	64	6.87 (0.42)	97
	WL	8.50 (3.24)	48	8.20(4.94)	46	8.15 (0.51)	48
SIAS-6	GU	5.73 (4.36)	98	4.26 (3.38)	66	4.64 (0.47)	98
	AM	5.85 (4.73)	96	4.73 (3.45)	59	4.67 (0.48)	96
	WL	5.81 (3.93)	48	5.82 (4.66)	44	5.69 (0.63)	48
SPS-6	GU	3.23 (3.28)	98	2.77 (3.05)	66	2.78 (0.41)	98
	AM	3.42 (4.22)	96	2.17 (2.74)	59	2.27 (0.42)	96
	WL	3.25 (3.64)	48	4.02 (4.89)	44	3.93 (0.54)	48
SNI	GU	10.63 (5.24)	98	11.14 (5.23)	70	11.11 (0.71)	98
	AM	11.33 (7.05)	97	11.55 (7.01)	64	11.74 (0.73)	97
	WL	11.50 (6.40)	48	12.11 (6.96)	46	12.02 (0.92)	48
RSES	GU	1.81 (0.65)	98	2.09 (0.55)	66	2.08 (0.07)	98
	AM	1.74 (0.70)	96	2.10 (0.58)	59	2.02 (0.08)	96
	WL	1.69 (0.72)	48	1.84 (0.64)	44	1.86 (0.10)	48
SWLS	GU	19.18 (5.93)	98	20.24 (6.37)	66	20.39 (0.70)	98
	AM	17.85 (5.97)	97	20.17 (6.52)	59	19.91 (0.72)	97
	WL	17.88 (7.19)	48	18.84 (6.98)	44	18.78 (0.94)	48
SOCS-S	GU	3.39 (0.64)	98	3.65 (0.59)	68	3.65 (0.07)	98
	AM	3.36 (0.66)	97	3.52 (0.70)	61	3.45 (0.08)	97
	WL	3.42 (0.65)	48	3.36 (0.57)	45	3.37 (0.09)	48
CBAS	GU	2.44 (0.75)	98	2.30 (0.61)	67	2.30 (0.08)	98
	AM	2.50 (0.76)	97	2.41 (0.67)	60	2.40 (0.08)	97
	WL	2.47 (0.80)	48	2.63 (0.82)	43	2.60 (0.11)	48
IJQ_tot	GU	1.61 (0.40)	97	1.45 (0.43)	64	1.47 (0.05)	97
	AM	1.65 (0.41)	91	1.46 (0.53)	53	1.50 (0.06)	91
	WL	1.73 (0.55)	47	1.67 (0.53)	44	1.67 (0.07)	47
DDI	GU	3.26 (0.82)	97	3.45 (0.69)	67	3.49 (0.09)	97
	AM	2.96 (0.82)	97	3.16 (0.76)	60	3.20 (0.09)	97
	WL	3.00 (0.91)	48	3.01 (0.83)	43	3.04 (0.12)	48
PID5BF+	GU	1.03 (0.31)	98	0.82 (0.32)	66	0.86 (0.04)	98
	AM	1.07 (0.35)	96	0.96 (0.33)	59	0.97 (0.04)	96
	WL	1.03 (0.31)	48	0.95 (0.35)	43	0.95 (0.05)	48
BVI	GU	1.64 (1.00)	98	1.44 (1.05)	66	1.42 (0.11)	98
	AM	1.79 (0.99)	97	1.54 (0.96)	59	1.53 (0.11)	97
	WL	1.68 (0.90)	48	1.67 (0.97)	44	1.70 (0.14)	48
KGAI-SF	GU	3.59 (0.53)	98	3.78 (0.49)	66	3.76 (0.06)	98
	AM	3.49 (0.59)	97	3.69 (0.56)	60	3.63 (0.06)	97
	WL	3.55 (0.50)	48	3.59 (0.47)	44	3.60 (0.08)	48
A-RSQ	GU	11.52 (4.00)	97	9.45 (4.02)	66	9.80 (0.48)	97
	AM	11.21 (4.38)	97	9.53 (4.26)	60	9.73 (0.50)	97
	WL	10.99 (4.34)	48	11.47 (5.06)	44	11.36 (0.63)	48
MSS-SF	GU	2.43 (0.64)	98	2.67 (0.65)	68	2.68 (0.07)	98
	AM	2.36 (0.66)	97	2.50 (0.67)	62	2.50 (0.08)	97
	WL	2.48 (0.59)	48	2.55 (0.66)	46	2.55 (0.09)	48
Lonely_dir	GU	1.88 (0.69)	98	1.13 (0.60)	68	1.17 (0.08)	98
	AM	1.95 (0.75)	96	1.27 (0.61)	62	1.32 (0.08)	96
	WL	1.98 (0.76)	48	1.57 (0.72)	46	1.57 (0.10)	48

Notes. UCLA-9 = 9-item version of the UCLA Loneliness Scale; PHQ-9 = 9-item Depression Module of the Patient Health Questionnaire; SIAS-6 = Social Interaction Anxiety Scale; SPS-6 = Social Phobia Scale; SNI = Social Network Index - size of social network ; SWLS: Satisfaction with life; RSES = Rosenberg Self-esteem Scale; SOCS-S = Sussex-Oxford Compassion for the Self Scale; CBAS = Cognitive-Behavioral Avoidance Scale – subscale Behavior-social avoidance ; IJQ_tot = Interpretation and Judgmental Bias Questionnaire – total score; DDI = Distress Disclosure Index; PID5BF+ = Personality Inventory for the DSM-5 Brief Form Plus; BVI = Bern Embitterment Inventory – subscale misanthropy; KGAI-SF = Kernis Goldman Authenticity Inventory - short form ; A-RSQ = Adult-Rejection Sensitivity Questionnaire; MSS-SF = the Motivation for Solitude Scale – Short Form; Lonely_dir = single item to assess loneliness directly ("Do you feel lonely?"). GU = SOLUS-D with guidance; AM = SOLUS-D with automated message; WL = waitlist control group.

Table 3. Within- and between-group effect sizes, overall effects, and contrasts at post-assessment for primary and secondary outcome measures.

Measure	Condition	Pre -post within-group effect sizes (estimated means)		Overall effects (Time × Group interaction)	Contrasts (at post-assessment)	Between-group effect sizes at post-treatment (estimated means)
		Cohen's d [95% CI]	n	F and *df*		Cohen's *d* [95% CI]
UCLA-9	GU	1.02 [0.71; 1.31]	98	$F_{(2,191.98)} = 8.22$ $p < .001$	WL vs. INT: $p = .002$ GU vs. AM: $p = .02$	GU vs. WL: -0.80 [-1.16; -0.44]
	AM	0.73 [0.43; 1.02]	97			GU vs. AM: -0.42 [-0.70; -0.13]
	WL	0.28 [-0.12; 0.68]	48			AM vs. WL: -0.34 [-0.60; 0.01]
PHQ-9	GU	0.89 [0.60; 1.18]	98	$F_{(2, 199.83)} = 6.91$ $p = .001$	WL vs. INT: $p = .004$ GU vs. AM: $p = .14$	GU vs. WL: -0.65 [-1.00; -0.29]
	AM	0.60 [0.31; 0.89]	97			GU vs. AM: -0.26 [-0.54; 0.02]
	WL	0.08 [-0.32; 0.48]	48			AM vs. WL: -0.39 [-0.73; -0.04]
SIAS-6	GU	0.28 [0.00; 0.56]	98	$F_{(2, 169.24)} = 2.35$ $p = .10$	-	GU vs. WL: -0.25 [-0.59; 0.10]
	AM	0.29 [0.00; 0.57]	96			GU vs. AM: -0.01 [-0.29; 0.27]
	WL	0.03 [-0.37; 0.43]	48			AM vs. WL: -0.23 [-0.57; 0.12]
SPS-6	GU	0.14 [-0.14; 0.42]	98	$F_{(2, 174.71)} = 7.10$ $p = .001$	WL vs. INT: $p = .02$ GU vs. AM: $p = .38$	GU vs. WL: -0.34 [-0.69; 0.01]
	AM	0.32 [0.04; 0.61]	96			GU vs. AM: 0.13 [-0.15; 0.42]
	WL	-0.16 [-0.56; 0.24]	48			AM vs. WL: -0.41 [-0.76; -0.06]
SNI	GU	-0.09 [-0.37; 0.19]	98	$F_{(2, 188.65)} = 0.007$ $p = .99$	-	GU vs. WL: -0.16 [-0.51; 0.18]
	AM	-0.06 [-0.34; 0.22]	97			GU vs. AM: -0.10 [-0.38; 0.18]
	WL	-0.08 [-0.48; 0.32]	48			AM vs. WL: -0.04 [-0.39; 0.30]
RSES	GU	-0.46 [-0.74; -0.17]	98	$F_{(2,178.36)} = 0.65$ $p = .52$	-	GU vs. WL: 0.33 [-0.02; 0.68]
	AM	-0.44 [-0.72; -0.15]	96			GU vs. AM: 0.09 [-0.19; 0.37]
	WL	-0.25 [-0.65; 0.15]	48			AM vs. WL: 0.23 [-0.12; 0.57]
SWLS	GU	-0.20 [-0.48; 0.09]	98	$F_{(2,172.48)} = 1.24$ $p = .29$	-	GU vs. WL: 0.24 [-0.04; 0.52]
	AM	-0.33 [-0.61; -0.05]	97			GU vs. AM: 0.08 [-0.20; 0.36]
	WL	-0.13 [-0.53; 0.27]	48			AM vs. WL: 0.17 [-0.11; 0.45]
SOCS-S	GU	-0.43 [-0.71; -0.14]	98	$F_{(2, 185.17)} = 5.06$ $p = .007$	WL vs. INT: $p = .09$ GU vs. AM: $p = .05$	GU vs. WL: 0.44 [0.09; 0.79]
	AM	-0.13 [-0.41; 0.15]	97			GU vs. AM: 0.31 [0.03; 0.59]
	WL	0.08 [-0.32; 0.48]	48			AM vs. WL: 0.13 [-0.22; 0.47]
CBAS	GU	0.20 [-0.08; 0.48]	98	$F_{(2,173.67)} = 4.26$ $p = .02$	WL vs. INT: $p = .05$ GU vs. AM: $p = .40$	GU vs. WL: -0.39 [-0.73; -0.04]
	AM	0.15 [-0.14; 0.43]	97			GU vs. AM: -0.13 [-0.41; 0.15]
	WL	-0.16 [-0.56; 0.24]	48			AM vs. WL: -0.25 [-0.60; 0.09]
IJQ_tot	GU	0.33 [0.04; 0.61]	97	$F_{(2,176.71)} = 0.84$ $p = .43$	-	GU vs. WL: -0.43 [-0.78; -0.08]
	AM	0.32 [0.03; 0.61]	91			GU vs. AM: -0.06 [-0.35; 0.22]
	WL	0.11 [-0.29; 0.52]	47			AM vs. WL: -0.37 [-0.72; -0.01]
DDI	GU	-0.31 [-0.59; -0.02]	97	$F_{(2,172.29)} = 2.55$ $p = .08$	-	GU vs. WL: 0.53 [0.18; 0.88]
	AM	-0.29 [-0.57; -0.01]	97			GU vs. AM: 0.36 [0.08; 0.64]
	WL	-0.05 [-0.45; 0.35]	48			AM vs. WL: 0.18 [-0.16; 0.53]
PID5BF+	GU	0.54 [0.25; 0.82]	98	$F_{(2, 171.04)} = 2.34$ $p = .10$	-	GU vs. WL: -0.30 [-0.63; 0.06]
	AM	0.28 [0.00; 0.56]	96			GU vs. AM: -0.34 [-0.63; -0.06]
	WL	0.25 [-0.15; 0.65]	48			AM vs. WL: 0.06 [-0.29; 0.40]
BVI	GU	0.22 [-0.07; 0.50]	98	$F_{(2, 173.40)} = 3.07$ $p = .05$	WL vs. INT: $p = .18$ GU vs. AM: $p = .46$	GU vs. WL: -0.29 [-0.64; 0.06]
	AM	0.27 [-0.02; 0.55]	97			GU vs. AM: -0.12 [-0.40; 0.17]
	WL	-0.02 [-0.42; 0.38]	48			AM vs. WL: -0.17 [-0.52; 0.17]
KGAI-SF	GU	-0.35 [-0.63; -0.07]	98	$F_{(2,174.09)} = 1.51$ $p = .22$	-	GU vs. WL: 0.31 [-0.03; 0.66]
	AM	-0.25 [-0.53; 0.03]	97			GU vs. AM: 0.24 [-0.04; 0.52]
	WL	-0.10 [-0.50; 0.30]	48			AM vs. WL: 0.06 [-0.29; 0.40]
A-RSQ	GU	0.42 [0.14; 0.71]	97	$F_{(2,177.15)} = 6.89$ $p = .001$	WL vs. INT: $p = .03$ GU vs. AM: $p = .92$	GU vs. WL: -0.38 [-0.73; -0.03]
	AM	0.34 [0.06; 0.62]	97			GU vs. AM: 0.02 [-0.27; 0.30]
	WL	-0.08 [-0.48; 0.32]	48			AM vs. WL: -0.37 [-0.72; -0.02]
MSS-SF	GU	-0.40 [-0.68; -0.12]	98	$F_{(2, 188.96)} = 2.00$ $p = .14$	-	GU vs. WL: 0.23 [-0.06; 0.51]
	AM	-0.21 [-0.49; 0.07]	97			GU vs. AM: 0.28 [0.00; 0.56]
	WL	-0.11 [-0.51; 0.29]	48			AM vs. WL: -0.07 [-0.35; 0.21]
Lonely_dir	GU	1.10 [0.79; 1.39]	98	$F_{(2,185.70)} = 2.70$ $p = .07$	-	GU vs. WL: -0.55 [-0.91; -0.20]
	AM	0.92 [0.62; 1.21]	96			GU vs. AM: -0.21 [-0.50; 0.07]
	WL	0.56 [0.15; 0.96]	48			AM vs. WL: -0.32 [-0.67; -0.03]

Notes. UCLA-9 = 9-item version of the UCLA Loneliness Scale; PHQ-9 = 9-item Depression Module of the Patient Health Questionnaire; SIAS-6 = Social Interaction Anxiety Scale; SPS-6 = Social Phobia Scale; SNI = Social Network Index - size of social network ; SWLS: Satisfaction with life; RSES = Rosenberg Self-esteem Scale; SOCS-S = Sussex-Oxford Compassion for the Self Scale; CBAS = Cognitive-Behavioral Avoidance Scale – subscale Behavior-social avoidance ; IJQ_tot = Interpretation and Judgmental Bias Questionnaire – total score; DDI = Distress Disclosure Index; PID5BF+ = Personality Inventory for the DSM-5 Brief Form Plus; BVI = Bern Embitterment Inventory – subscale misanthropy; KGAI-SF = Kernis Goldman Authenticity Inventory - short form ; A-RSQ = Adult-Rejection Sensitivity Questionnaire; MSS-SF = the Motivation for Solitude Scale – Short Form; Lonely_dir = single item to assess loneliness directly ("Do you feel lonely?"). GU = SOLUS-D with guidance; AM = SOLUS-D with automated message; WL = waitlist control group, INT = SOLUS-D with guidance and SOLUS-D with automated message taken together.

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Erklärung zur Dissertation

Hiermit bestätige ich, dass ich die Dissertation (Titel):

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im Fach Klinische Psychologie und Psychotherapie

unter der Leitung von PD Dr. Tobias Krieger

ohne unerlaubte Hilfe ausgeführt und an keiner anderen Universität zur Erlangung eines akademischen Grades eingereicht habe.

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