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Stability and Change in Intolerance of Uncertainty and Its Association with Interpretation Bias in Social Situations: A Longitudinal Study of Italian Adolescents

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Abstract: Background: Intolerance of Uncertainty (IU) is a transdiagnostic factor measured using the Intolerance of Uncertainty Scale-Revised (IUS-R). This study evaluated the stability and change in adolescents' IU over a three-month period using a modified version of the scale. Methods: A two-wave study was conducted, with 290 adolescents responding to an online survey at baseline and 199 at follow-up. The original IUS-R was modified to probe the rating of the current perceived state of IU, rather than typical experience. The link between IU variability and the development of interpretation bias in ambiguous social situations at follow-up was explored. Structural Equation Modeling and Linear Mixed Model analyses were performed to assess the longitudinal measurement invariance and responsiveness of the Modified IUS-R scale. Results: The scale demonstrated good psychometric properties and full measurement invariance. Individual participants showed significant variability in baseline IU levels but not in the degree of change. A reliable change in scores was observed in 8% of adolescents. The Modified IUS-R predicted interpretation bias in social situations at follow-up. Conclusions: Significant inter-individual-level variation in IU suggests this tool may be useful for detecting changes in IU and predicting significant health outcomes. Future studies should further address the assessment of changing IU with longer timeframes.

Keywords: intolerance of uncertainty; stability and change; state and trait theory; negative interpretation bias; adolescents; social anxiety

Citation: Lauriola, M.; Malerba, A.; Marini, M.; Parisse, C.; Prislei, L.; Bottesi, G.; Livi, S. Stability and Change in Intolerance of Uncertainty and Its Association with Interpretation Bias in Social Situations: A Longitudinal Study of Italian Adolescents. *Adolescents* **2024**, *4*, 564–586. https://doi.org/10.3390/adolescents4040040

Received: 15 October 2024
Revised: 11 December 2024
Accepted: 13 December 2024
Published: 19 December 2024

1. Introduction

Adolescence represents a critical developmental window characterized by rapid biological, hormonal, and social-environmental changes. Concurrent with these transformations, the brain in this period undergoes significant maturation, leading to more sophisticated cognitive abilities and an increase in the complexity of future-oriented thinking and self-awareness [1,2]. These developments in cognitive processing equip adolescents with the necessary tools for self-reflection, social cognition, and future planning. In some individuals, the adolescent years might be marked by positive adaptation to stress and challenges [3]. However, for other individuals, this confluence of factors can make adolescence a vulnerable time for the onset of mental health disorders [1,4,5].

A recent study by Sivertsen et al. [6], employing a longitudinal design, analysing data from two population-based studies separated by 6 years, demonstrated a robust association between mental health problems in adolescence and subsequent mental health difficulties in young adulthood. This continuity was observed across various mental health domains and remained statistically significant after controlling for confounding variables. These results supported the notion that early onset of mental health problems may act as a general risk factor for later mental illness. Furthermore, the data indicated both homotypic and heterotypic continuities, suggesting transdiagnostic risk factors may be critical in understanding psychopathology development.

1.1. Trait and State Intolerance of Uncertainty

Intolerance of Uncertainty (IU) is defined as an "individual's dispositional incapacity to endure the aversive response triggered by the perceived absence of salient, key, or sufficient information, and sustained by the associated perception of uncertainty" [7] (p. 31). It is a transdiagnostic vulnerability factor, being associated with several dysfunctional behaviours and a range of emotional disorders [8]. Over the past decade, research into transdiagnostic mechanisms maintaining emotional disorders has gained significant momentum. Transdiagnostic approaches focus on identifying and addressing factors that transcend traditional diagnostic boundaries, contributing to the maintenance of multiple disorders. The rationale for these approaches is supported by evidence, such as shared genetic heritabilities, common latent structures, similar efficacy of treatments across disorders, high comorbidity rates, and the remission of comorbid conditions during treatment for a primary disorder (see [9] for a review). Accordingly, recent research has extended the investigation of IU's role in adolescent psychopathology beyond anxiety and depression to include externalizing behaviours and eating disorders. For instance, Oglesby et al. [10] found that IU was associated with using alcohol to cope with tension and anxiety and drinking for social conformity and peer acceptance in a non-clinical sample. Additionally, IU was identified as a significant factor in adolescents with restrictive eating disorders, where uncertainty was perceived negatively and managed through restrictive eating behaviours, which provided a sense of safety and control [11].

IU is also trans-situational, playing a role in various contexts defined by uncertainty. Freeston et al. [12] defined Uncertainty Distress (UD) as "the subjective negative emotions experienced in response to the as yet unknown aspects of a given situation" [12] (p. 2) and proposed the Uncertainty Distress Model (UDM) to describe the interaction between life events, threat and uncertainty, IU and situational IU, and UD. IU drives perceptions of more significant uncertainty about the outcome in an uncertain context, leading to greater perceived threat severity [13]. The UDM assumes that the individual's response to uncertainty relies on IU (a trait-like, dispositional tendency) and its context-specific state component, which is expected to wax and wane based on the interaction between the person and the situation.

The fluctuating component of IU (hereafter referred to as "State IU") has been under scrutiny [8], although research in this area is in its infancy. Indeed, some authors have pursued incremental predictive validity by developing instruments that emphasize the situation-specific component of IU, probing IU associated with diagnostically relevant situations [14,15]. To assess situation-specific IU, Mahoney and McEvoy [14] introduced the IUS-SS, focusing on a single situation related to the individual's primary concern (e.g., social anxiety). Thibodeau et al. [15] expanded this approach with the Disorder-Specific IU scale (DSIU), allowing for multiple situations and identifying specific uncertainty-related stressors in the context of six nosological domains. While these measures advanced our understanding of IU's phenomenology, they do run the risk of departing from the transdiagnostic validity of IU in favour of a disorder-specific focus [16].

Research spanning the last 15 years has evidenced age differences in IU, as assessed with different measures of the construct [17–20], among adolescents, albeit not univocally. Among cross-sectional studies confronting early (i.e., 10–12 years), middle (i.e., 13–16 years), and late (i.e., 17–19 years) adolescents, some have reported higher IU levels in late adolescence [18,20,21], while others have found early adolescents scoring higher [17,19] or no difference at all [22]. In a longitudinal study, Dugas et al. [23] found that adolescents scored higher at the beginning (12–13 years) and the end of secondary school (17–18 years), reporting IU means across 5 years in ten waves. These mean differences might be interpreted as non-specific, spurious stress-induced inflations in a typically stable component, or as phase-specific, transitional changes in how adolescents face uncertainty in an ever-changing environment demanding increasing autonomy. Alternatively, they might be merely associated with bias due to group differences in response to the scale's items. The evaluation of measurement invariance is critical to tease apart these aspects.

Measurement invariance ensures that differences observed in scores are due to genuine differences in the construct rather than artefacts of the measurement instrument itself. To our knowledge, measurement invariance in adolescent samples has only been evaluated in the Chinese [18] and Italian [19] translations of the IU scale, finding full scalar and partial scalar invariance, respectively. Having established full invariance, Haoxian et al. [18] found that the mean age of the "High IU" profile was significantly higher than that of the "Medium IU" and "Low IU" profiles in a very large sample of 108,540 adolescents. Conversely, Bottesi et al. [19] found higher IU levels in pre-adolescents (11–13 years), although scalar non-invariance precluded any conclusions on mean differences between age groups. Finally, Lauriola et al. [24] found lower scores in older adolescents, albeit only at T1. While cross-sectional age differences and measurement invariance are insufficient to delineate the within-person trajectories, they might coexist with them. Although evidence suggests IU may fluctuate across time or situations, no measure has been validated to assess intraindividual fluctuations in State IU.

1.2. Intolerance of Uncertainty and Interpretation Bias in Social Anxiety

Social Anxiety Disorder (SAD) is defined as a "Marked fear or anxiety about one or more social situations in which the individual is exposed to possible scrutiny by others". (DSM-5-TR; [25]) (p. 230). Individuals with SAD fear being negatively evaluated due to their behaviour or symptoms of anxiety. The disorder commonly onsets in childhood [26]. However, symptoms increase during adolescence with a prevalence of 5–16% [27], a stage of the life cycle in which social anxiety may intensify due to the physical and social changes associated with puberty [28–30]. The presence of SAD during adolescence is often linked to impairments in both academic and social functioning, as evidenced by research examining its impact on academic performance [31] and social interactions [30,32–34]. Adolescents with social anxiety are at heightened risk for adverse health outcomes, including peer victimization [35], depression, and substance abuse [36]. Given these significant consequences, early detection and intervention are crucial, underscoring the importance of ongoing research on factors contributing to the onset and maintenance of SAD. In cognitive models, threat- and uncertainty-related schemas underpin anxiety and, when activated, guide cognitive processing in response to threat and uncertainty [37–39].

Among others, IU has been shown to be robustly associated with symptoms of SAD [14,40]. IU was found to be associated with social anxiety on both self-report and behavioural measures through a bias in the interpretation of uncertain social situations [41]. Individuals with high levels of social anxiety and IU may be particularly vulnerable to experiencing uncertainty about their ability to maintain positive social interactions. This heightened uncertainty can lead to a stronger motivation to avoid social experiences rather than tolerating the associated feelings of uncertainty [40].

Concerning the fluctuating nature of IU, an interesting insight was recently put forward by Kruganski et al. [42]. These authors posited that the perceived valence of anticipated outcomes in specific uncertain or ambiguous situations, such as social ones, exhibits a "hydraulic relationship" [42] (p. 36) with the valence of recent experiences, wherein the influence of recent experiences diminishes over time, while the impact of long-term outcomes endures. According to their theory, grounded on direct and indirect empirical evidence, these long-term outcomes, such as adverse childhood experiences or positive parenting styles, shape stable tendencies to react positively or negatively to uncertainty. In contrast, short-term outcomes more directly influence future expectations [42]. In sum, when faced with uncertainty, individuals' affective responses are shaped by their long- and short-term past experiences, and these experiences inform their expectations regarding the potential outcomes of uncertain events. This theory underscores the role of recent experiences in shaping expectations, which is consistent with the UDM, as proposed by Freeston et al. [12], in emphasising the role of contingent life events in forming specific responses to uncertainty.

Interpretation bias (IB) is a cognitive distortion marked by the consistent tendency to attribute threatening interpretations to ambiguous stimuli [43]. IU and IB have been recognised as related constructs, particularly in the context of anxiety disorders. A growing body of evidence supported the notion that individuals with high levels of IU exhibit a negative IB, interpreting ambiguous or uncertain information as more threatening compared to those with lower IU levels [41,44,45].

Studies by Dugas et al. [44] and Koerner and Dugas [46] showed that adults with high levels of IU exhibited heightened concern over uncertain scenarios. In further developing these findings, Oglesby et al. [47] employed tasks designed to directly measure the automatic negative interpretation of uncertain information, thereby providing more compelling evidence that adults with high IU do demonstrate a negative IB for uncertain information. Specifically, participants with elevated IU were more likely to associate uncertain phrases (e.g., "Doctor called") with negative interpretations (e.g., "I have a terrible disease") rather than with neutral ones (e.g., "Appointment reminder"). Notably, IU was not associated with a generalised negative interpretation bias but rather with uncertainty-related stimuli. This suggested a selective vulnerability to uncertainty rather than a broad tendency to interpret all information negatively. This results in heightened anxiety in uncertain situations. These negative biases, in turn, contribute to the onset or exacerbation of anxiety-related psychopathologies such as SAD, as suggested by recent findings linking IU and IB with these conditions [41].

Existing research has signalled the prevalence of various cognitive biases in social anxiety. Adolescents experiencing social anxiety are more predisposed to perceive ambiguous social cues as threatening and to anticipate rejection or blame from their peers [48]. These biased social interpretations can trigger self-protective and avoidance behaviours, which, in turn, maintain anxiety [49,50]. According to the cognitive model for SAD, developed by Clark and Wells [51], socially anxious individuals display an IB. Indeed, social cues are incomplete and ambiguous in social occasions, be they the actual event or the anticipation of it [52]. Accordingly, Amir and Bomyea [53] highlighted the relevance of IB in SAD research, noting the inherently ambiguous nature of social interactions.

As shown in two meta-analyses, IB has an established role in social anxiety in adults and adolescents [37,54]. Studies on adolescents [55,56] have shown that negative IB is a dimensional feature of social anxiety, increasing in parallel with anxiety levels, and, thus, may be a valuable predictor of SAD development. Moreover, the link between IB and anxiety also seems to increase in strength from childhood to adolescence [37].

1.3. The Present Study: Aims and Hypotheses

The primary purpose of this study was to evaluate the stability and change of IU in adolescents over an observation period of approximately three months, with two time points: baseline and follow-up. To increase the likelihood of detecting change, if any, over time, we modified the existing version of the IUS-R by emphasizing a time-specific evaluation framework. In particular, we revised the original IUS-R items and instructions, asking participants to evaluate their feelings, attitudes, and beliefs in the present moment rather than as usual (see Supplementary Materials for the modified IUS-R scale and instructions, available in both Italian, Table S1, and English, Table S2, versions). To avoid confounding changes in the IU construct with changes due to other factors unrelated to IU, we tested its longitudinal measurement invariance. Longitudinal invariance ensures that the measurement model of the Modified IUS-R remains stable over time. This allowed us to confidently assess changes in IU without concern that observed differences were due to changes in the assessment method (e.g., learning or practice effects) rather than true changes in the underlying trait or state. We hypothesized that there would be full metric and scalar invariance between the baseline and follow-up assessments (H1) (see Section 2). If supported, measurement invariance would suggest that any observed changes in the Modified IUS-R scores over time reflected true changes in IU across the two time points.

Following the measurement invariance testing, we hypothesized that the variance in Modified IUS-R scores could be decomposed into a stable trait component and a fluctuating state component, which varies between measurement occasions in differing amounts for each person (H2). To test this assumption and quantify the amounts attributed to each component, we used a Linear Mixed Model (LMM) analysis. In this model, we posited a random intercept to represent each adolescent's average level across the two time points, a random slope to represent the change from baseline to follow-up for each adolescent, and a fixed within-subjects effect to capture the overall sample trajectory over time, independent of the trait and state components. A significant random intercept would support the claim that adolescents differed in their IU level (i.e., in the stable trait component). A significant random slope would support the claim that each adolescent deviated from his/her baseline level in a variable amount (i.e., the fluctuating intraindividual state component). As for the fixed slope, since previous research has found that the average IU level of adolescents should be fairly stable at the mean age of our sample (i.e., 16 years old), we hypothesized that there was no significant fixed within-subjects effect during the observation period.

A further objective of this study was to explore the predictive relationship between adolescents' baseline IU levels and their IB in ambiguous social scenarios at follow-up. Specifically, we hypothesized that baseline IU levels would predict IB at follow-up (H3). Moreover, we hypothesized that the stability of IU in adolescents would be a key factor influencing IB (H4). Accordingly, we tested whether the relationship between baseline IU and IB at follow-up was mediated by IU levels at follow-up.

2. Materials and Methods

2.1. Participants

Participants were recruited from a secondary school in Rome, Italy, as part of a broader study aimed at investigating the processes of social inclusion and exclusion within classroom settings, as well as the dynamics that influence student cohesion. Therefore, 290 adolescents aged between 14 and 18 completed all the measures at baseline (M_{age} = 15.86 years, SD_{age} = 1.04; 57.6% girls, 40.7% boys, 1.7% undisclosed). At follow-up, 199 adolescents responded to the survey (M_{age} = 15.83 years, SD_{age} = 1.02; 58.3% girls, 39.7% boys, 2% undisclosed), resulting in a 31.38% dropout rate between the two waves.

2.2. Procedures

Prior to participation, written informed consent was obtained from the parents or guardians of minor students. However, even with parental consent, minors were required to express their personal willingness to participate in the study. Adolescents over the legal age (i.e., 18 years) independently provided their consent. All participants received detailed information about the research objectives, methodologies, and instruments during questionnaire completion. Participation was voluntary, and adolescents were informed they could withdraw at any time without providing a reason. Data collection through online survey administration took place during school hours, with a teacher and at least one researcher in the classroom. This study was approved by the Institutional Review Board of the University of Cagliari, Italy, and was conducted in accordance with the Declaration of Helsinki.

2.3. Instruments

2.3.1. Intolerance of Uncertainty

In the present study, IU was assessed using a modified version of the IUS-R [19,57]. The IUS-R is a refined version of the original IUS-12 [58], which was revised with simplified language to be easily understood by an average 11-year-old individual. It measures the tendency to find uncertainty upsetting and distressing, with higher scores indicating greater IU. The IUS-R encompasses two dimensions: prospective IU, referring to the predisposition for active information seeking to reduce uncertainty, and inhibitory IU, expressing avoidance-oriented reactions to uncertainty. Participants were asked to rate 12 items on how each one applies to them on a 5-point Likert scale, ranging from 1 = not at all agree to 5 = completely agree. The Italian version of the IUS-R has demonstrated excellent internal consistency (Cronbach's α = 0.84–0.90) and good one-month test–retest reliability (r = 0.74) in an adolescent sample [24]. For the present study, we adapted the IUS-R by modifying instructions and response scale. Specifically, we asked participants to "Think about how you currently feel in situations of uncertainty and indicate how much you feel as described. If you find it helpful, you can refer to how you felt in the last week when you were in a situation of uncertainty". Additionally, the response scale was modified to assess the intensity of responses to uncertainty rather than general agreement, in line with previous studies aiming to capture state changes [59,60]. In the present sample, the Modified IUS-R showed excellent internal consistency (Cronbach's α = 0.91, Bentler's ω = 0.88, McDonald's ωh = 0.80) and good three-month test–retest reliability (r = 0.61).

2.3.2. Interpretation Bias

IB was assessed using the Italian version of the Adolescents' Interpretation and Belief Questionnaire (AIBQ; [61]). It is a questionnaire designed to measure IB in adolescents. The AIBQ presents 10 ambiguous scenarios that are age-appropriate for the participants. Five scenarios involve non-social situations (e.g., discovering that one's bicycle is no longer where it was left), while the other five depict common social situations in school life (e.g., giving a presentation to classmates). After each scenario, a question is posed to emphasize the ambiguity and prompt the participant to consider possible explanations for the event, offering one positive, one negative, and one neutral interpretation. Participants were asked to rate how likely each interpretation would come to mind in that situation on a 5-point scale (1 = would not come to mind, 5 = would definitely come to mind). Finally, the three interpretations are presented again, and participants must choose which one they believe is most likely to be true. Thus, the AIBQ includes eight subscales, positive interpretation, negative interpretation, neutral interpretation, and belief in negative interpretation, with four scales applied to social situations and four to non-social situations. Higher scores indicate a higher probability of endorsing positive, neutral, or negative IB, depending on the scale. Higher scores in the Social and Non-Social Negative Belief scales indicate a higher probability of choosing the negative interpretation out of the three. The two scales of the AIBQ measuring social negative interpretation and belief in negative interpretation in social situations demonstrated good convergent validity with the Social Phobia Inventory Scale, a measure of social anxiety severity [62]. Additionally, these scales effectively discriminated between adolescents without SAD and those with a SAD diagnosis [61]. In the present sample, the AIBQ scales showed internal consistency values in line with the ones found in the Italian validation study (Cronbach's α = 0.15–0.70) [61]. This is the only instrument available in the literature for evaluating the interpretation bias in adolescents, and it has been previously used in other Italian studies [63,64].

2.4. Research Design and Statistical Analysis

2.4.1. Research Design

The current study utilized an observational, two-wave longitudinal design, with follow-up conducted three months after baseline.

2.4.2. Missing Value Analysis

A missing value analysis was conducted to assess the potential impact of attrition on our study results. Little's Missing Completely at Random (MCAR) test was employed to determine whether the missing data patterns deviated from a purely random distribution. By confirming the MCAR assumption ($X^2 = 12.35$, $df = 10$, $p = 0.263$), we validated the use of all available cases for model parameter estimation.

2.4.3. Structural Equation Modelling

Structural Equation Modelling (SEM) analyses were performed to evaluate the factorial structure of the Modified IUS-R and assess its measurement invariance between baseline and follow-up, addressing H1. In accordance with previous studies carried out on the original IUS scales in young adults and adolescents [19,58,65], we tested the following models: a single-factor model representing a general IU construct (Figure 1a), a two-factor model with correlated factors representing prospective and inhibitory IU (Figure 1b); (3) a bifactor model positing a common factor, representing general IU, and two group factors representing inhibitory and prospective IU, respectively (Figure 1c).

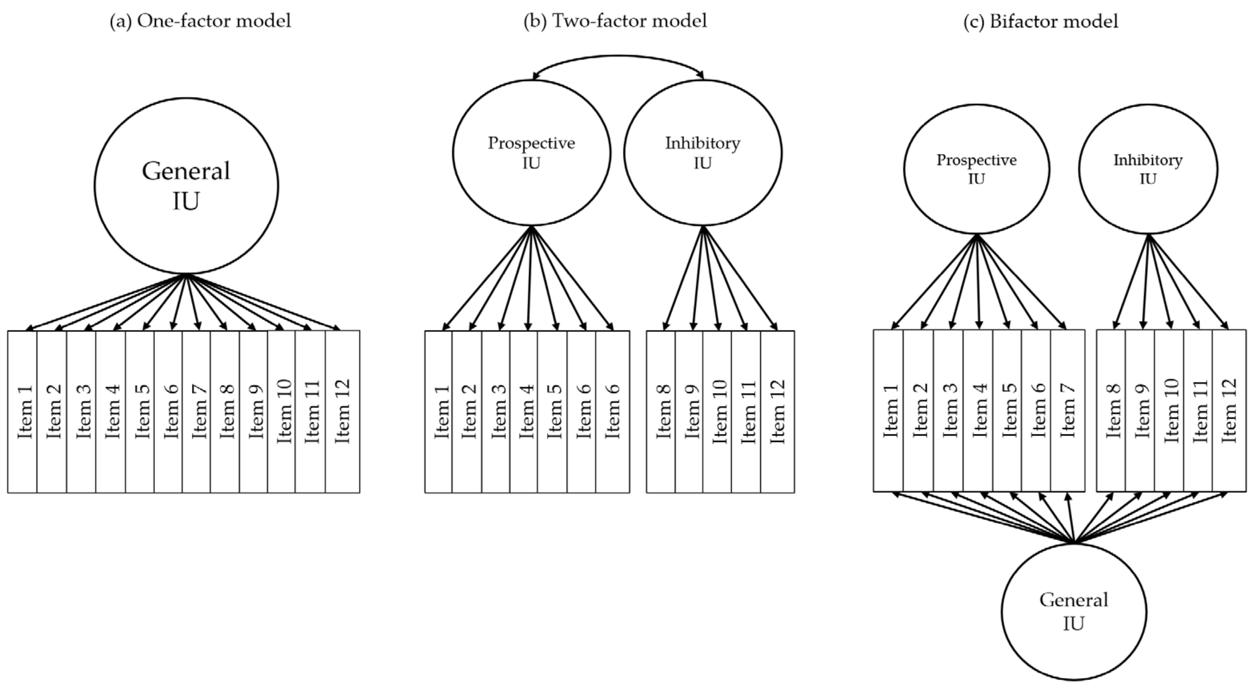

Figure 1. Alternative factor models for the Modified IU scale. (**a**) One-factor model with a general Intolerance of Uncertainty (IU) factor. (**b**) Two-factor model with separate prospective IU and inhibitory IU factors. (**c**) Bifactor model where both prospective and inhibitory IU, as well as a general IU factor, explain variance independently across items.

Because the Modified IUS-R used ordinal categorical items, we analysed the polychoric correlations using Diagonally Weighted Least Squares (DWLS) estimators. This analysis is recommended for handling ordinal data and has no distributional assumptions [66]. Model fit was assessed using the following fit indexes and the associated cut-offs: Comparative Fit Index (CFI > 0.95), Tucker–Lewis Index (TLI > 0.95), Root Mean Square Error of Approximation (RMSEA < 0.06), and Standardized Root Mean Square Residual

(SRMR < 0.05). Measurement invariance was tested by evaluating the decline in model fit across increasingly constrained models. Configural invariance examined whether the same items measured the same latent variables across different time points. Metric invariance introduced equality constraints on factor loadings across time points. Scalar invariance for ordered categorical variables required the equality of item thresholds rather than item intercepts. While metric invariance ensured that a unit change in the latent variables remained comparable over time, scalar invariance confirmed that changes in the latent variable were free from construct-irrelevant item-level biases. The scaled chi-square difference test was used to determine whether a more parsimonious model fit the data as well as a less parsimonious one, thus indicating the level of invariance achieved. According to Chen [67], a change in CFI $\leq$ 0.010, along with changes in RMSEA of -0.015 and SRMR of -0.030 (for metric invariance) or -0.015 (for scalar invariance), was considered evidence for substantial equivalence in model fit, even if the chi-square difference test was statistically significant.

As indicated by Rodriguez et al. [68], the results of the bifactor model can be used to determine whether the total score of a psychometric instrument serves as a good proxy for the general factor or if the construct's multidimensionality suggests that subscale scores should be used instead. The standardized factor loading matrix was analysed using Dueber's [69] bifactor indices calculator to derive the following indices. The Explained Common Variance (ECV) assesses the proportion of variance in IUS items explained by the general factor relative to the total amount of common variance. The coefficient ω reflects the overall proportion of reliable variance in the total score attributable to both general and group factors. In contrast, ωh indicates the proportion of variance accounted for by the general factor alone. Small differences between ω and ωh suggest that the total score may be preferable over subscale scores. A similar logic applies to group factors, where ωs represents the overall proportion of reliable variance in a subscale score, while ωsh reflects the reliable variance common to specific groups of items.

According to Reise et al. [70], when the PUC is less than 0.80, the ECV for the general factor exceeds 0.60, and when ωh for the general factor is greater than 0.70, the level of multidimensionality is not strong enough to preclude interpreting the instrument as predominantly unidimensional without risking structural parameter bias.

2.4.4. Linear Mixed Model Analysis

To quantify the variance explained by trait, state, and change contingent upon the study time points, testing H2, the Modified IUS-R scores were analysed using an LMM. The analysis incorporated a random intercept so that each individual was allowed to have their own average level of IU across two time points. The random slope in the model reflected how each individual changed their IU level across the two time points. The fixed effect of time point was included to estimate the sample's trajectory over time, independent of the trait and state components. The analysis used the Restricted Maximum Likelihood, which estimates the fixed effects after accounting for the random effects, making it preferable for models where the primary interest is in variance components. *p*-values were corrected using the Satterthwaite approximation. We estimated and compared two nested models: a random-intercept model, which included both the fixed effect of time and the random intercept, and a full model that incorporated the fixed effect, the random intercept, and the random slope. By comparing the fit of these models, we assessed whether the inclusion of a random slope, which captured fluctuations in State IU, explained a significant additional portion of variance beyond the random intercept, which reflected the stability of trait IU over the course of this study. The proportion of variance accounted for by each model was assessed using marginal and conditional R^2 values, reflecting the proportion of variance explained by the fixed effects only and both the fixed and random effects.

2.4.5. Reliable Change Index

In order to quantify a reliable change at an intraindividual level (H2), we calculated the Reliable Change Index (RCI) for each subject. The RCI is a ratio of the difference between the adolescent's scores on the two measurement occasions and the standard error of measurement for the differences in the scores. Generally, the RCI is larger when the difference score is considerably greater than the standard error of measurement and when scores vary widely between two measurement occasions. A difference is deemed reliable if the observed difference score exceeds the instrument's RCI. We considered a difference of ±1.96, corresponding to a 95% confidence level, as indicative of reliable change.

2.4.6. Mediation Analyses

A series of mediation analyses were conducted to examine the indirect and direct effects of IU at baseline on IB in social and non-social situations at follow-up. Each analysis aimed to test whether the Modified IUS-R at baseline predicted AIBQ scores at follow-up, both directly (H3) and indirectly through Modified IUS-R at follow-up (H4). The total effect of IU at baseline on IB was calculated as the sum of the direct and indirect effects. The estimates were derived using bias-corrected bootstrap resampling (with 5000 bootstrap samples), allowing for more accurate confidence intervals of indirect effects. Confidence intervals (95% CI) were computed for all effects, and statistical significance was determined by whether the confidence intervals did not include zero. The results were reported with standardized effect sizes (β), standard errors (SE), z-scores, and *p*-values.

3. Results

3.1. Descriptive Analyses

The data from the Modified IUS-R and AIBQ were analysed to assess normality, skewness, and kurtosis in the total sample and separately for gender groups (see Table 1). For the total scores of the Modified IUS-R at baseline, skewness and kurtosis values suggested an approximately normal distribution; however, the Shapiro–Wilk test indicated a significant deviation from normality. This discrepancy likely reflected minor variations in the shape of the distribution, as indicated by a W value of 0.99 in the total sample (where 1.00 represents perfect normality). A similar pattern was observed for both boys and girls at baseline. At follow-up, skewness and kurtosis again suggested an approximately normal distribution, yet the Shapiro–Wilk test revealed a minor, significant deviation from normality (W = 0.98). For boys, the data displayed slight right skewness and a leptokurtic distribution, confirmed by a significant Shapiro–Wilk test result (W = 0.94), which nonetheless remained within tolerance limits. In contrast, the data for girls showed no significant deviations, approaching perfect normality (W = 0.99). For the AIBQ scores, despite significant Shapiro–Wilk test results for both social and non-social subscales, the test values consistently remained above 0.95, approaching 0.99 in most cases. Boys and girls similarly exhibited significant Shapiro–Wilk tests despite only minor differences in skewness and kurtosis. The only variables raising concerns about normality were the AIBQ Positive and Negative Beliefs scales for social and non-social situations, where the Shapiro–Wilk test results were significant, and the values were relatively distant from perfect normality.

Table 1. Descriptive statistics and normality tests for the Modified IUS-R and AIBQ scales at baseline and follow-up by gender.

Variable	Sample	n	*M*	*SD*	Min	Max	Skewness	Kurtosis	W	*p*
Modified IUS-R (Baseline)	Total	290	35.46	9.98	12	60	0.08	0.04	0.99	0.015
	Boys	118	32.35	9.96	12	60	0.27	0.40	0.98	0.038
	Girls	167	37.78	9.37	15	60	0.10	−0.13	0.99	0.249

Table 1. *Cont.*

Variable	Sample	n	*M*	*SD*	Min	Max	Skewness	Kurtosis	W	*p*
Modified IUS-R (Follow-up)	Total	277	35.12	10.08	12	60	0.23	0.14	0.98	0.002
	Boys	79	31.10	9.69	12	60	0.76	1.68	0.94	0.001
	Girls	116	37.39	9.32	12	60	0.00	0.13	0.99	0.583
AIBQ Negative Interpretation Social (Follow-up)	Total	277	2.66	0.80	1.0	5.0	0.40	0.22	0.98	<0.001
	Boys	79	2.54	0.76	1.0	4.8	0.35	1.05	0.96	0.010
	Girls	116	2.76	0.75	1.2	5.0	0.71	0.61	0.96	0.002
AIBQ Positive Interpretation Social (Follow-up)	Total	277	2.62	0.67	1.0	4.4	−0.08	−0.10	0.99	0.012
	Boys	79	2.65	0.70	1.0	4.0	−0.38	−0.21	0.97	0.052
	Girls	116	2.57	0.66	1.0	4.4	0.26	0.10	0.98	0.194
AIBQ Neutral Interpretation Social (Follow-up)	Total	277	3.27	0.73	1.0	5.0	−0.28	0.92	0.98	<0.001
	Boys	79	3.28	0.83	1.0	5.0	−0.15	0.38	0.98	0.199
	Girls	116	3.29	0.70	1.4	5.0	0.06	0.38	0.98	0.114
AIBQ Beliefs Social (Follow-up)	Total	277	2.55	0.40	1.0	3.2	−0.86	1.11	0.93	<0.001
	Boys	79	2.59	0.40	1.2	3.2	−1.03	1.62	0.92	<0.001
	Girls	116	2.51	0.39	1.2	3.2	−0.69	0.67	0.95	<0.001
AIBQ Negative Interpretation Non-Social (Follow-up)	Total	277	2.79	0.57	1.0	4.4	−0.05	0.18	0.99	0.011
	Boys	79	2.70	0.63	1.2	4.2	−0.13	−0.13	0.98	0.283
	Girls	116	2.83	0.51	1.6	4	−0.11	−0.16	0.98	0.058
AIBQ Positive Interpretation Non-Social (Follow-up)	Total	277	3.17	0.63	1.0	4.6	−0.25	0.63	0.98	<0.001
	Boys	79	3.24	0.71	1.0	4.6	−0.44	0.70	0.98	0.134
	Girls	116	3.23	0.57	1.8	4.6	0.01	0.05	0.98	0.100
AIBQ Neutral Interpretation Non-Social (Follow-up)	Total	277	2.80	0.58	1.0	4.4	0.08	0.42	0.98	0.001
	Boys	79	2.82	0.60	1.4	4.4	0.08	0.24	0.98	0.145
	Girls	116	2.79	0.57	1.0	4.4	0.14	0.64	0.98	0.030
AIBQ Beliefs Non-Social (Follow-up)	Total	277	2.90	0.49	1.0	3.8	−1.46	2.31	0.84	<0.001
	Boys	79	2.87	0.46	1.4	3.4	−1.69	2.33	0.78	<0.001
	Girls	116	2.93	0.45	1.4	3.8	−1.16	1.49	0.89	<0.001

Legend. AIBQ = Adolescents Interpretation and Belief Questionnaire; Modified IUS-R = Modified Intolerance of Uncertainty Scale- Revised; W = Shapiro–Wilk test statistic.

3.2. Factor Structure and Measurement Invariance

The first step in studying longitudinal invariance is to establish a measurement model that fits well with the data collected at both baseline and follow-up. The measurement models typically evaluated for the standard IUS-R included the single-factor model, the two-factor model with correlated factors, and the bifactor model (see Section 2 and Figure 1). Table 2 presents the fit indices for each model at baseline and follow-up. At both time points, the bifactor model demonstrated the best fit, making it the foundation for subsequent invariance analyses. While the two-factor model also showed a good fit, the high correlation between the factors (r = 0.84) suggested substantial overlap and raised concerns about the divergent validity of the prospective and inhibitory IU factors [71]. Therefore, the bifactor model was considered the most appropriate for further analysis.

Table 2. Fit indices for the confirmatory factor analysis of the Modified IUS-R models at baseline and follow-up.

Model	n	X^2 (*df*)	ΔX^2 (*df*)	CFI	TLI	RMSEA	LLCI	ULCI	SRMR
Baseline	199								
One-Factor		152.00 (54) ***	-	0.990	0.987	0.096	0.078	0.114	0.069
Two-Factor		94.53 (53) ***	54.47 [a] (1) ***	0.996	0.995	0.063	0.042	0.083	0.052
Bifactor		48.36 (42)	46.16 [b] (11) ***	0.999	0.999	0.028	0.000	0.058	0.038
Follow-up	199								
One-Factor		313.71 (54) ***	-	0.977	0.972	0.156	0.139	0.173	0.096
Two-Factor		125.65 (53)	188.06 [a] (1) ***	0.994	0.992	0.083	0.065	0.102	0.060
Bifactor		43.55 [c] (43)	-	1.000	1.000	0.008	0.000	0.049	0.036

Legend. CFI = Comparative Fit Index; TLI = Tucker–Lewis fit Index; RMSEA = Root Mean Square Error Of Approximation; LLCI = Lower Limit Confidence Interval; ULCI = Upper Limit Confidence Interval. Models computed using Diagonally Weighted Least Squares (DWLS) estimation. $\Delta\chi^2$ computed using the R lavaan package compareFit function. [a] $\Delta\chi^2$ comparing unidimensional and correlated two-factor models in both samples. [b] $\Delta\chi^2$ comparing correlated two-factor and bifactor models at T1. [c] For identification purposes, the factor loadings on the general factor for items 4 and 8 were equalized. *** $p < 0.001$.

Table 3 reports the fit indices for the bifactor model in the multi-time-point analysis. The configural model showed an excellent fit, comparable to the fit obtained separately at baseline and follow-up. The metric invariance model also exhibited an excellent fit. Although the chi-square difference test comparing the metric invariance model to the configural model was statistically significant ($\Delta X^2 = 79.91$, $df = 21$, $p < 0.001$), metric invariance was supported according to Chen [67], as the ΔCFI was less than 0.010, ΔRMSEA was ≤0.015, and ΔSRMR was ≤0.030. The scalar invariance model, which imposed equality constraints on item thresholds across time points, also demonstrated an excellent fit. The chi-square difference test comparing the scalar invariance model to the metric invariance model was not statistically significant ($\Delta X^2 = 35.36$, $df = 48$, $p = 0.912$).

Table 3. Fit indices and tests of longitudinal measurement invariance for the bifactor model of the Modified IUS-R.

Model	X^2 (*df*)	CFI	TLI	RMSEA (CI)	SRMR	$\Delta\chi^2$ (*df*)	ΔCFI	ΔTLI	ΔRMSEA	ΔSRMR
Configural	148.64 (207)	1.000	1.003	0.000 (0.000–0.000)	0.037	-	-	-	-	-
Metric	228.56 (228)	1.000	1.000	0.004 (0.000–0.030)	0.046	79.91 [a] (21) **	0.000	−0.003	0.004	0.008
Scalar	263.92 (276)	1.000	1.000	0.000 (0.000–0.023)	0.046	35.36 [b] (48)	0.000	0.000	−0.004	0.000

Note. $n = 199$. *Legend*. χ^2 = chi-square; *df* = degrees of freedom; $\Delta\chi^2$ = chi-square difference test; CFI = Comparative Fit Index; TLI = Tucker–Lewis fit index; RMSEA = Root Mean Square Error Of Approximation; CI = Confidence Interval; ΔCFI = change in Comparative Fit Index; ΔTLI = change in Tucker–Lewis Fit Index; ΔRMSEA = change in Root Mean Square Error of Approximation; ΔSRMR = change in Standardized Root Mean Square Residual. Models computed using Unweighted Least Squares (ULS) estimation. [a] $\Delta\chi^2$ comparing configural and metric models. [b] $\Delta\chi^2$ comparing metric and scalar models. ** $p < 0.01$.

To explore potential changes in the means of the general IU factor, as well as the prospective and inhibitory factors, we tested a model that constrained the latent factor means to zero at baseline and freely estimated them at follow-up. The chi-square difference test comparing this latent mean difference model to the scalar invariance model was not statistically significant ($\Delta X^2 = 1.40$, $df = 3$, $p = 0.706$), indicating that the free parameters were unnecessary. Consequently, no statistically significant Standardized Mean Difference (SMD) was detected: SMD = 0.06 ($p = 0.407$) for the general factor, SMD = −0.157 ($p = 0.281$) for the prospective IU factor, and SMD = −0.05 ($p = 0.717$) for the inhibitory IU factor. These results indicated that there was no significant change in the average levels of IU over the study period at the latent factor level.

Table 4 presents the Standardized Factor Loading matrix and the Standardized Residual Variance for the Bifactor Model. The general factor explained approximately four-fifths of the common variance (ECV = 0.79), while the remaining one-fifth was accounted for by group factors. The Percentage of Uncontaminated Correlation (PUC), which represents the percentage of covariance attributable solely to the general factor, was 0.53. The proportion of reliable variance in the total score explained by the general factor (ωh = 0.84) was slightly lower than the total reliable variance (ω = 0.94). The ωs coefficients were 0.90 for prospective IU and 0.91 for inhibitory IU; however, when the variance attributed to the general factor was removed, these coefficients dropped to 0.16 and 0.18, respectively.

Table 4. Standardized Factor Loadings and Standardized Residual Variance for the Bifactor Model of the Intolerance of Uncertainty scale in the adolescent sample.

			Bifactor Model		
Item	**UFL**	**BSRV**	**General**	**Prospective**	**Inhibitory**
1. At the moment, unforeseen events agitate me a lot.	0.78	0.36	0.73	0.32	-
2. At the moment, not having all the information I need is a nuisance.	0.76	0.35	0.67 ***	0.45 ***	-
3. Right now, I need to look ahead to avoid surprises.	0.66	0.44	0.58 ***	0.47 **	-
4. Lately, I feel that a small setback can ruin everything, even with the best planning.	0.79	0.32	0.80 ***	0.19 *	-
5. At the moment, I want to know what will happen in the future.	0.63	0.57	0.61 ***	0.25 **	-
6. Lately, I can't stand being taken by surprise.	0.71	0.44	0.74 ***	0.12	-
7. Currently, I feel I must be able to plan everything in advance.	0.55	0.58	0.51 ***	0.39 **	-
8. At the moment, uncertainty prevents me from living a full life.	0.75	0.36	0.76 ***	-	0.27
9. Lately, if it is time to act, uncertainty paralyzes me.	0.71	0.34	0.67 ***	-	0.45 **
10. Currently, if I do not know what may happen, I cannot do things well.	0.82	0.29	0.75 ***	-	0.38 **
11. At the moment, even the smallest doubt can prevent me from acting.	0.76	0.28	0.68 ***	-	0.51 **
12. Lately, I feel that I have to get away from all uncertain situations.	0.76	0.39	0.76 ***	-	0.18 *
Omega Coefficients			ω = 0.94 ωh = 0.84	ωs = 0.90 ωsh = 0.16	ωs = 0.91 ωsh = 0.18
H			0.92	0.49	0.47
ECV			0.79		
PUC			0.53		

Note. n = 199. *Legend*: H = construct replicability index; ECV = Explained Common Variance; PUC = Percentage of Uncontaminated Correlations. UFL = Unidimensional Factor Loadings. BSRV = Bifactor Standardized Residual Variance. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

3.3. Variance Components Associated with Trait Stability and State Change

The LMM, which included a random intercept, random slope, and the fixed within-subjects effect of time, was overall statistically significant ($\chi^2 = 95.73$, $df = 5$, $p < 0.001$) and accounted for approximately 89% of the variance in adolescents' IU ratings. Consistent with the latent mean difference analysis, the fixed effect representing the overall sample trajectory over time was not statistically significant using the Modified IUS-R total score instead of the latent factor score ($F_{1,198} = 0.00$, $p = 1.000$), indicating that the average IU level of the sample remained stable throughout the study period. The random components accounted for all the variance in the dataset. To determine which random effects contributed most to the within-subject variance, we compared the full model with the nested model, where the random slope effect was removed. The nested model was still statistically significant ($\Delta\chi^2 = 95.70$, $df = 3$, $p < 0.001$) and accounted for 61% of the variance. However, the statistical comparison between the full and nested models did not reach significance ($\Delta\chi^2 = 0.04$, $df = 3$, $p = 0.981$). Given the lack of a significant difference between the models, the more parsimonious model should be preferred. This finding indicated that the random slope included in the full model did not significantly improve the model's fit. The random intercept alone was sufficient, implying that in the study period, the inter-individual variance (associated with the trait component of IU) was the only relevant source of variation. Although the random slope explained about 28% of the variability in IU ratings, our analysis indicated that the state fluctuations observed in this study were not sufficient to reach statistical significance. As depicted in Figure 2, the nearly flat mean trajectory showed that, on average, participants' Modified IUS-R scores remained stable throughout the study period, with no significant overall change between the two time points. Conversely, a broad range of individual trajectories was observed, most of which followed the general sample trend despite starting from different baseline levels. These gradients illustrated the variability associated with the trait component of IU.

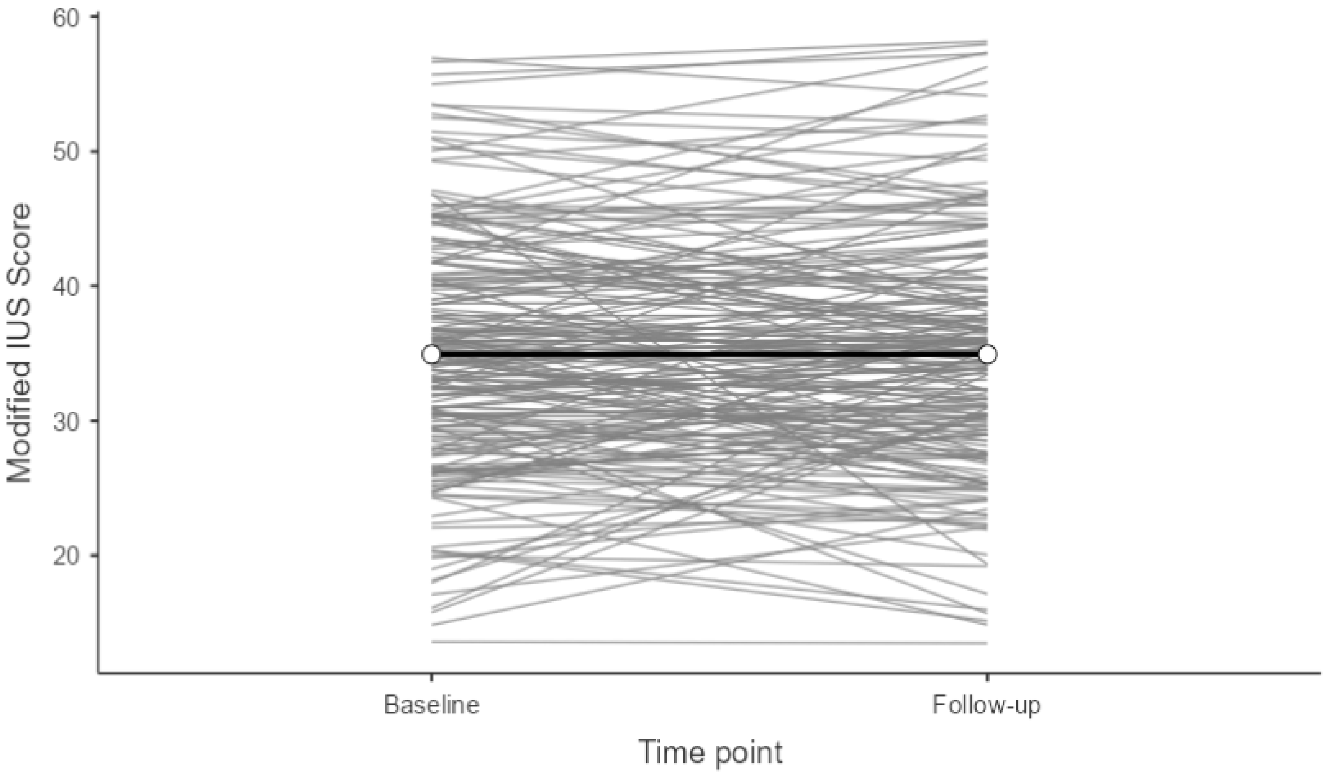

Figure 2. Individual and mean trajectories of Modified IUS scores from baseline to follow-up. Each thin grey line represents a participant's score trajectory, while the thick black line represents the overall sample mean trajectory. White circles on the black line indicate mean IUS scores at each time point.

A careful inspection of Figure 2 reveals that while some adolescents showed an increase in their levels of IU, others exhibited a decrease; however, these trajectories represented a minority. To quantify these intraindividual variations, we conducted an analysis of reliable change. In this analysis, we first calculated the test–retest reliability using the intraclass correlation method, resulting in a coefficient of 0.61, indicating moderate stability three months later [72]. Using this reliability estimate, we calculated the RCI for each subject. The results of this classification allowed us to detect a reliable change in State IU true scores in 8% of our sample. Specifically, the change at three months occurred asymmetrically, with a reliable increase in scores observed in 5% of adolescents and a reliable decrease in 3%.

3.4. Predictive and Mediation Analyses

To examine the predictive relation between IU and IB in ambiguous social and non-social scenarios, we utilized the Modified IUS-R scores at baseline to predict AIBQ scores at follow-up. The analysis of ambiguous social scenarios yielded statistically significant results for both AIBQ positive ($F_{1,197} = 10.44$, $p < 0.001$) and negative interpretation scores ($F_{1,197} = 24.02$, $p < 0.001$). Higher baseline IU scores predicted lower endorsement of positive interpretations (B = −0.02; SE = 0.00; β = −0.22; t = −3.23; $p < 0.001$) and higher endorsement of negative interpretations in ambiguous social scenarios (B = 0.03; SE = 0.01; β = 0.33; t = 4.90; $p < 0.001$), accounting for 5% and 11% of the variance, respectively. The analysis of non-social scenarios was statistically significant only for negative interpretation scores ($F_{1,197} = 13.15$, $p < 0.001$), with baseline IU scores predicting higher endorsement of negative interpretations in ambiguous non-social scenarios (B = 0.01; SE = 0.00; β = 0.25; t = 3.63; $p < 0.001$), with R^2 = 6%. The analysis of social beliefs was not statistically significant. In summary, higher IU was consistently linked to an increased negative IB in both social and non-social situations, alongside a decrease in positive interpretations of social situations.

Table 5 reports the results of mediation analyses examining the predictive role of baseline Modified IUS-R scores on AIBQ scores through Modified IUS-R scores at follow-up. For positive interpretations in ambiguous social scenarios, baseline Modified IUS-R scores had a significant negative direct effect, but the indirect effect was non-significant. In contrast, for ambiguous non-social scenarios, neither the direct nor indirect effects were significant, suggesting that baseline IU had no strong impact on positive interpretations in non-social contexts. For neutral interpretations, baseline IU scores showed no significant direct effects in either social or non-social scenarios. For negative interpretations, the analyses revealed strong mediation effects in both social and non-social scenarios. In ambiguous social scenarios, both the direct and indirect effects were significant, leading to a highly significant total effect. A similar pattern was observed in non-social scenarios, where the indirect effect and total effects were significant. These results indicated that baseline IU levels strongly predicted adolescents' negative interpretations in both social and non-social ambiguous scenarios, while IU effects on positive and neutral interpretations were weaker and perhaps more context dependent. The mediation analysis indicated that IU played a mediating role in the relation between baseline IU and future interpretations, particularly for negative interpretations.

Table 5. Mediation analyses of Modified Intolerance of Uncertainty Scale-Revised (IUS-R) scores predicting AIBQ positive, neutral, negative interpretations, and beliefs in ambiguous social and non-social scenarios (panels a and b, respectively).

Panel a. Ambiguous Social Scenarios						**Panel b. Ambiguous Non-social Scenarios**					
	Dependent: AIBQ Positive Interpretation						**Dependent: AIBQ Positive Interpretation**				
Effect	B	LLCI	ULCI	β	*p*	Effect	B	LLCI	ULCI	β	*p*
Indirect	0.00	−0.01	0.01	0.02	0.651	Indirect	0.01	0.00	0.01	0.09	0.098
Direct	−0.02	−0.03	0.00	−0.25	0.004	Direct	0.00	−0.01	0.01	−0.03	0.753
Total	−0.02	−0.02	0.00	−0.22	0.001	Total	0.00	−0.01	0.01	0.06	0.372
	Dependent: AIBQ Neutral Interpretation						**Dependent: AIBQ Neutral Interpretation**				
Effect	B	LLCI	ULCI	β	*p*	Effect	B	LLCI	ULCI	β	*p*
Indirect	0.01	0.00	0.02	0.07	0.173	Indirect	0.01	0.00	0.01	0.10	0.065
Direct	0.00	−0.01	0.02	0.06	0.530	Direct	−0.01	−0.02	0.00	−0.13	0.152
Total	0.01	0.00	0.02	0.13	0.065	Total	0.00	−0.01	0.01	−0.03	0.722

Table 5. *Cont.*

Panel a. Ambiguous Social Scenarios						Panel b. Ambiguous Non-social Scenarios					
Dependent: AIBQ Negative Interpretation						**Dependent: AIBQ Negative Interpretation**					
Effect	B	LLCI	ULCI	β	*p*	Effect	B	LLCI	ULCI	β	*p*
Indirect	0.01	0.00	0.02	0.14	0.008	Indirect	0.01	0.00	0.02	0.15	0.004
Direct	0.01	0.00	0.03	0.19	0.022	Direct	0.01	0.00	0.02	0.10	0.261
Total	0.03	0.02	0.04	0.33	< 0.001	Total	0.01	0.01	0.02	0.25	0.000
Dependent: AIBQ Beliefs						**Dependent: AIBQ Beliefs**					
Effect	B	LLCI	ULCI	β	*p*	Effect	B	LLCI	ULCI	β	*p*
Indirect	0.00	−0.01	0.00	−0.08	0.140	Indirect	0.00	0.00	0.01	0.01	0.822
Direct	0.00	−0.01	0.01	−0.06	0.493	Direct	0.01	0.00	0.01	0.12	0.182
Total	−0.01	−0.01	0.00	−0.14	0.044	Total	0.01	0.00	0.01	0.13	0.063

Legend. Indirect = baseline Modified IUS-R scores predict the dependent variable at follow-up through Modified IUS-R scores; Direct = baseline Modified IUS-R scores predict the dependent variable at follow-up; Total = Direct + Indirect; AIBQ = Adolescents Interpretation and Belief Questionnaire; LLCI = Lower Limit Confidence Interval; ULCI = Upper Limit Confidence Interval. *Note.* Confidence intervals are computed using the bias-corrected bootstrap method. Betas are completely standardized effect sizes.

4. Discussion

The primary objective of the present study was to examine the stability and change of IU in adolescents over three months, assessing this construct using a modified version of the IUS-R with a time-specific evaluation framework. Moreover, this study also aimed to assess its association with IB at follow-up, both directly and indirectly through IU at follow-up. The initial analysis of the Modified IUS-R items revealed a bifactor structure consistent with the existence of a general IU factor underlying adolescents' ratings, along with two distinct group factors capturing prospective and inhibitory IU, respectively. This result aligns with previous research on the latent structure of IU in adolescents, which initially suggested a two-factor model [73] but has since evolved to support a bifactor model highlighting a dominant general IU factor [19]. Although bifactor models often show better incremental and absolute fit indices [74], they are less parsimonious. However, while the two-factor model exhibited an acceptable fit, the high correlation between prospective and inhibitory IU factors pointed to an essentially unidimensional structure. Notably, the single-factor model demonstrated poor fit, reinforcing the preference for the bifactor solution. The bifactor model indices (i.e., PUC, ECV, and ωh) indicated that although some evidence of multidimensionality exists, the total score of the Modified IUS-R can be considered essentially unidimensional and can be used as such in both research and clinical applications [70].

The present study demonstrated that emphasizing a time-specific evaluation framework did not compromise the scale's dimensionality or reliability. On the contrary, in analysing the factor loading pattern of the bifactor model, it was observed that the factor loadings in the present study were more satisfactory compared to previous research [19,75]. This suggests that the Modified IUS-R could offer a more robust structure when focusing on time-specific assessments. In particular, all factor loadings on the group factors were significant, except for one item. In contrast, Bottesi et al.'s [19] bifactor model analysis reported that only three factor loadings were significant, and one was negative. The challenge of identifying group factors is not unique to the IUS-R but extends to the adult versions of the IUS scales, particularly affecting the prospective IU factor [76,77]. At present, it remains unclear whether the changes in instructions or item wording contributed to this better result in our study or if it is merely an incidental finding specific to the sample in this study. Further replication in future studies would allow for more definitive conclusions regarding the influence of these modifications.

Before addressing the stability and change in IU, the longitudinal measurement invariance of the Modified IUS-R factors was tested. The results supported full scalar longitudinal invariance, confirming H1 in that the factors maintained the same measurement unit and baseline levels over time. Additionally, latent mean difference analysis revealed that the overall IU level remained stable in adolescents over the three-month period. This finding aligns with expectations, given that the average age of our sample corresponds to a period of relative IU stability according to previous studies [17,18,20–23]. However, it did not shed light on the relative importance of trait and state components at the intraindividual level.

To cope with this problem, the total variability in adolescent ratings was decomposed into a part due to stable interindividual differences over time (i.e., the trait component) and a part due to changes over time differing individual by individual (and not already explained by factors contingent on the study period). The results only partially confirmed our hypotheses (H2). We certainly expected a significant proportion of variance explained by individuals in the trait IU, which was largely supported in this study. The expectation was also that the Modified IUS-R would be sensitive enough to detect intraindividual changes, resulting in a significant amount of variance explained by this component in the analysis model. Contrary to expectations, while explaining about 30% of the variability in the data, the model's random slope was not shown to explain an additional share of variance compared to the random intercept alone. Through computation of RCI on our sample, we sought to quantify the detected, albeit non-significant, intraindividual variability. Reliable change was observed in 8% of adolescents. It should be noted that this is a conservative estimate. Indeed, there is consensus in the literature that while the RCI allows for the estimation of confidence in true score changes with just two measurements, it also suffers from relatively wide confidence intervals, which tend to favour false negatives to minimize false positives (i.e., mistaking measurement error for real changes in scores) [78].

Several possible explanations for the non-significance of intraindividual variability were considered.

The first account for negative findings concerning intraindividual change could be that self-reported IU had been rather stable and, perhaps, processed by the individual as a dispositional tendency. Under this light, we might argue that when reporting their feelings, attitudes, and beliefs towards uncertainty in the present moment rather than as usual, adolescents might have lacked the insight needed to compare their current state to their general tendency to react aversively to uncertainty, even when prompted to do so. Conversely, assuming that adolescents have sufficient insight to distinguish between how they usually react to uncertainty and how they react at a specific time, the study results could be interpreted by considering that simply altering the IUS-R instructions and items was insufficient to effectively elicit state-specific responses. Perhaps the concept of uncertainty and intolerance may be too abstract to be grasped in its temporal evolution in the daily experience of adolescents, unless anchored to concrete experiences.

A second explanation for the lack of significant findings could be the relative brevity of the observation period. A three-month duration might not have provided enough time to capture meaningful intraindividual changes in IU. The existing literature indicates that if any changes in IU are observed, they typically emerge over years rather than months [23]. However, the literature primarily focused on measuring trait IU. Although we hypothesized that assessing State IU would effectively capture short-term fluctuations, the results did not support this expectation. At this time, we must acknowledge that changes in State IU may only become apparent over longer periods, even when a time-specific evaluation framework is explicitly utilized.

Third, it is worth noting that changes reported in the literature often coincided with transitional periods. Consistent with this view, it is important to consider that most of the sample was aged 15 to 16. Existing studies suggest that normative changes in IU, if any, would emerge either during early or late adolescence when individuals face uncertainty associated with important developmental tasks [17,18,20–23]. Therefore, the absence of a detectable change in our study might be due to the fact that most participants were not in a transitional phase but rather a period of relative stability in IU.

Lastly, the research design of this study may have lacked the necessary time depth to detect intraindividual changes that might have been observable with the inclusion of three measurement time points. For example, studies with two time points may be suitable for examining group-level or intervention effects, whereas more complex questions about individual differences and their underlying causes and consequences might require additional time points to adequately model change [79].

The last goal of our study was to leverage the two-wave research design to explore whether IU, measured through the Modified IUS-R, could predict adolescents' tendency to negatively interpret ambiguity-rich social situations. H3 was fully supported, with baseline IU accounting for approximately 10% of the variance in adolescents' negative interpretations in ambiguous social scenarios and around 5% in non-social scenarios. These findings align with the existing literature, demonstrating the relation between cognitive biases, particularly IB and IU, which exacerbate anxiety in ambiguous social contexts. For instance, IB, which is prevalent among adolescents with SAD, has been shown to lead to negative interpretations of ambiguous social cues, perpetuating anxiety [37,54]. The present study contributes to the literature by extending evidence of the IU-IB relationship in a non-clinical sample. Additionally, while most previous research employed cross-sectional designs, this study is, to our knowledge, the first to test a predictive relationship in a longitudinal framework, albeit over a relatively short time period. Finally, to our knowledge, this is the first study to explore the relationship between IB and a measure of Intolerance of Uncertainty in a sample of adolescents. Specifically, it is also the first time the AIBQ is employed conjunctly with a measure of IU. The results, which signal a predictive relationship between IU and negative IB, suggest that further studies in the adolescent population are warranted to explore this relationship and dissect incremental predictive utility in clinical populations. Future studies could also explore the potential utility of IU-focused interventions in reducing IB and social anxiety symptoms in youth, in line with efforts already made [47].

Furthermore, testing the indirect effects of baseline IU on IB through IU at follow-up yielded significant results for negative IB in both social and non-social situations. These findings provided support for H4, which proposed that the stability of IU would mediate the relationship between baseline IU and IB at follow-up. Notably, the indirect effect included an autoregressive path linking baseline IU to follow-up IU. The significance of the autoregressive path indicates that IU at follow-up was influenced by its prior levels at baseline, reflecting the persistence of the construct over time. Accordingly, part of the predictive relation found in this study could be explained by the stability of IU over the observation period. That is, adolescents who had higher IU scores at the beginning of the study and maintained these levels by the end of the observation period were more likely to experience negative thoughts regarding the interpretation of both social and non-social scenarios. This process seems consistent with previous research in adolescents with SAD, in which IU was found to be robustly associated with social anxiety [14,40] and thought to maintain anxiety symptoms because of overly negative interpretation of ambiguous social cues in social interactions [37,54].

5. Conclusions

The present study addressed a gap in the literature, investigating the validity of a modified version of the IUS-R to assess the stability and change of IU in adolescents over a three-month observation period. Moreover, it explored its predictive relationship with IB in social and non-social scenarios.

The novel measure demonstrated solid psychometric properties, namely a good fit for the bifactor measurement model, excellent internal consistency, and good test–retest reliability. Longitudinal measurement invariance testing confirmed that the Modified IUS-R maintained stable measurement properties over time. Latent mean difference analysis revealed no significant change in IU at the group level, aligning with the expectation of stability during mid-adolescence. While a significant trait component was identified, there was limited evidence of intraindividual state variability, possibly due to the brevity of the observation period or adolescents' difficulty conceptualizing state-specific IU.

Concerning IU and IB, the present results supported the hypothesized relationship between baseline IU and adolescents' negative IB in ambiguous social and non-social scenarios. Additionally, the stability of IU mediated this predictive relationship, suggesting that adolescents with consistently high IU were more likely to exhibit negative IB over time. These findings align with the literature linking IU to cognitive biases and anxiety, contributing novel evidence from a longitudinal framework. The results underscore the utility of the Modified IUS-R in capturing IU and highlight the importance of IU in understanding cognitive biases during adolescence.

In conclusion, it is worth summarizing this research's major limitations, which, nonetheless, open the way for future studies. To begin with, a significant limitation of this study was the relatively short observation period of three months, mainly due to the need to reconcile the study of IU as part of a larger project on the school population. Therefore, future studies should consider a longer observation window, for example, one year, to increase the likelihood of detecting the expected changes. Relatedly, this study predominantly included adolescents aged 15 to 16, a period marked by relative stability in IU according to existing research. Future studies should aim to include a broader age range to capture both early and late adolescents, as these groups may be experiencing transitional periods that could influence changes in IU over time. An accelerated longitudinal design, which follows up multiple single cohorts, each one starting at a different age, could be particularly suited for this purpose [80]. A third limitation was that we employed only two measurement points, which might not be sufficient to model individual-level change accurately. Future research could address this by conducting a three-wave study, employing SEM with intraindividual SEM analyses [81] or latent state–trait models [82] to differentiate trait and state components from measurement error in the overall variance and comparing the results with those from the original IUS-R. Despite the fact that we modified the IUS-R to emphasize present-moment evaluations, the fourth limitation of the present study was that the scale did not detect a significant intraindividual change in IU over time. It is possible that adolescents struggled to distinguish between their general tendency to react to uncertainty and their momentary state, limiting the study's ability to capture state-specific fluctuations in IU. Future studies could explore this by adopting alternative strategies to elicit State IU, for example, asking the participant to narrate a recent episode of uncertainty and to respond to the scale while thinking about how they felt and reacted on that occasion. This is in line with the approach chosen by Bottesi et al. [83] in their measure of uncertainty-reducing behaviours [84] and might also prove useful for measuring intraindividual uncertainty-related cognitions and distress. Finally, in the present study, information on ethnicity and socioeconomic status is lacking.

The results of our research might have possible applicative implications for the prevention of social anxiety problems in non-clinical adolescents. The stability of IU observed in this study suggests that IU might work as a trait-like vulnerability factor for social anxiety. Since IU was found to predict negative interpretations of ambiguity in social and non-social situations, interventions could focus on helping adolescents reframe their interpretations of ambiguous situations, particularly in social contexts, to prevent a possible onset of social anxiety symptoms. In this regard, psychoeducational interventions in the school setting targeting maladaptive IU beliefs might be effective for adolescents with elevated IU to reduce negative interpretation bias.

Moreover, our findings suggest that a one-size-fits-all intervention might not be optimal, as some adolescents may experience persistent high levels of IU while others may show variability. Interventions targeting trait IU have been implemented in undergraduates with difficulties tolerating uncertainty following access to the university's counselling service. This preliminary evidence suggested their effectiveness in reducing distress and anxiety levels [85]. The UDM framework highlights the significant role of contingent factors in shaping situational IU, even in non-clinical settings. Consequently, interventions targeting IU in adolescents could benefit from prioritizing situational IU, which may be more malleable than trait IU. For instance, brief school-based interventions aimed at improving adolescents' situational tolerance of uncertainty could serve as effective preventive strategies, especially for individuals with high trait IU, potentially reducing the risk of developing more severe or clinically significant distress.

Supplementary Materials: The following supporting information can be downloaded at https://osf.io/9awup/. Table S1. Title: Modified IUS-R with instructions, Italian version. Table S2. Title: Modified IUS-R with instructions, English version.

Author Contributions: Conceptualization, M.L. and A.M.; data curation, M.M., C.P. and L.P.; formal analysis, M.L., A.M., M.M., C.P. and L.P.; funding acquisition, S.L.; investigation, S.L.; methodology, M.L. and A.M.; project administration, S.L.; resources, S.L.; supervision, G.B.; validation, M.M., C.P. and L.P.; visualization, A.M.; writing—original draft, M.L., A.M., M.M., C.P. and L.P.; writing—review and editing, M.L., A.M., G.B. and S.L. All authors have read and agreed to the published version of the manuscript.

Funding: This research is part of a broader project funded by SAPIENZA University of Rome, under Grant RD12318A949D7606.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of the University of Cagliari, Italy (protocol code 000610, 4 January 2024).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study or their parents if adolescents were under the legal age.

Data Availability Statement: The data presented in this study are openly available from 15 October 2024, from OSF at https://osf.io/9awup/.

Acknowledgments: The authors used commercial generative artificial intelligence to assist with grammar checking and improving the form and presentation of the manuscript. The content, however, remains original and was developed entirely by the authors. After employing AI tools, the authors thoroughly reviewed and edited the text to ensure accuracy and coherence and take full responsibility for the final content of the publication.

Conflicts of Interest: The authors declare no conflicts of interest.

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