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ORIGINAL CONTRIBUTION

Mediators of the association between psychotic experiences and future non-suicidal self-injury and suicide attempts: results from a three-wave, prospective adolescent cohort study

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Abstract

Psychotic experiences (PEs) are robustly associated with subsequent non-suicidal self-injury (NSSI) and suicide attempts, but questions remain as to the temporal relation and underlying cause of this association. Most investigations have incorporated only two waves of data, and no study has comprehensively investigated mediating pathways. This study aimed to investigate both the PE-NSSI and PE-suicide attempt association, and their relevant mediators, across three waves of prospective data. Participants were from an Australian prospective longitudinal cohort of 1100 adolescents (12–17 years); data were collected at three time points over 2 years. NSSI and suicide attempts were measured using the Self-Harm Behaviour Questionnaire. Items from the Diagnostic Interview Schedule for Children were used to assess four PE subtypes (auditory hallucinatory experiences [HEs] and three delusional experiences). Potential mediators of interest included: psychological distress, self-reported mental disorders, self-esteem, recent traumatic life events (e.g. bullying, sexual assault), emotion regulation, and impulsivity/other personality traits. Analyses were adjusted for sociodemographics and substance use. Auditory HEs were indirectly associated with future NSSI and suicide attempts via recent traumatic life events, high psychological distress, and low self-esteem, across three waves of data. Other PE subtypes were generally not associated with incident NSSI/suicide attempts at 1- and 2-year follow-up, either directly or indirectly. These findings highlight the importance of screening for auditory HEs when assessing a young person's self-harm/suicide risk. Clinical assessment would be further enhanced by a comprehensive review of recent interpersonal traumatic events, as well as levels of self-esteem and distress.

Keywords Hallucinations · Delusions · Self-injurious behavior · Self-harm · Non-suicidal self-injury · NSSI · Suicide · Adolescents · Mediators

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Introduction

Psychotic experiences (PEs), including hallucinatory and delusional experiences, are common among adolescents [1, 2] and are associated with a broad range of adverse health and social outcomes including non-suicidal self-injury (NSSI; self-harm without suicidal intent) and suicidal thoughts and behaviours [3–5]. PEs prospectively predict NSSI [6, 7] and suicide attempts [8–10] among adolescents, with large effect sizes, and studies have reported dose–response relationships with regard to both number of PEs [11, 12] and lethality of suicidal behaviour [8, 13, 14]. Whilst the association between PEs and self-injurious behaviours (i.e. NSSI and suicide attempts) has been well-replicated, questions remain as to the temporal relation and underlying cause of these associations.

Most studies have restricted their examination of the PE-self injurious behaviour association to auditory hallucinations [8, 13] or collapsed all types of PEs into one variable [6, 15]. The few studies of adolescents that have investigated different types of PEs (e.g., hallucinatory, persecutory ideation, and bizarre experiences) have found differential strengths in the associations [12, 16], suggesting that some PEs are more likely to be associated with self-injurious outcomes than others. Hielscher et al. [4] investigated five different PE subtypes (auditory and visual hallucinatory experiences, and three delusional experiences) using a cross-sectional nationally representative sample of Australian adolescents. After comprehensive adjustment and consideration for relevant confounders and mediators, only auditory hallucinatory experiences were independently associated with NSSI and suicide attempts [4]. Longitudinal data are required to inform the temporal nature of these associations. To our knowledge, nearly all longitudinal studies to date investigating PE-NSSI or PE-suicide attempt associations have used two waves of data collection, which can be an unreliable source for understanding how two variables affect each other over time. Observing an event at "Time 1" and seeing its impact at "Time 2" offers more insight than a cross-sectional study, however, if one accepts the premise that a longitudinal design should enhance our understanding of relationships and how they change over time, longitudinal designs should ideally contain a minimum of three waves, to allow for more reliable observation of a relationship over time [17]. The first aim of this study was to investigate the association between different PE subtypes and future NSSI and suicide attempts among adolescents using a three-wave prospective cohort study.

Previous investigations of the PE-self injurious behaviour association have inconsistently adjusted for, or considered third variables (i.e. confounders, mediators, moderators). Hielscher et al. [18] reported that 30% of existing studies did not control or account for any third variables of interest. Honings et al.'s [19] meta-analysis found that adjusting for depression resulted in attenuation of the PE-self injurious behaviour association (including NSSI, deliberate self-harm, suicide attempts), which remained significant for all outcomes except deliberate self-harm. It is possible that the PE-self injurious behaviour association is explained entirely by mediators, but studies using structural equation modelling, and using three waves of longitudinal data [20] are needed to explore this possibility, allowing for distinction and quantification of the role of mediators versus confounders (and other third variables). Therefore, the second aim of this study was to investigate several potential mediators of the PE-NSSI and PE-suicide attempt association using this methodology.

Identifying and assessing the influence of mediators is important in understanding the mechanisms involved in the PE-self injurious behaviour association, which may in turn inform interventions to prevent self-injurious behaviour and suicide [8, 13]. Mediators help explain why the relationship between two variables exists (whereas moderators, for example, explain the strength of a relationship [21, 22]). In terms of key mediating variables of interest, a systematic review of the PE-self-injurious behaviour association [18] identified several clinical and psychosocial variables (e.g. common mental disorders, psychological distress) as potentially important explanatory variables, and Hielscher et al.'s [4] cross-sectional study of adolescents found major depressive disorder had the greatest explanatory power in all PE-NSSI/suicide attempt associations, followed by psychological distress and bullying. Low self-esteem was also a key explanatory variable in the delusional experience-self injurious behaviour association [4]. All these variables should be considered candidates for further examination as mediators of the association.

In addition to these key variables, broader negative and traumatic life events need to be considered in the PE-self-injurious behaviour association [8, 23], but to date have not been extensively investigated [18]. In DeVylder et al.'s [24, 25] fully adjusted models, bullying and childhood physical/sexual trauma attenuated the association with nearly all suicidal outcomes, and Gaweda et al.'s [26] cross-sectional study found PEs and depression mediated the childhood trauma-suicidal behaviour relationship. The roles of historical (childhood trauma) as well as more recent traumatic events (e.g. sexual assault, bullying) during adolescence need to be considered in the PE-self injurious behaviour association. Although emotion dysregulation is theorised to play a key role in the development of self-injury [27, 28], only two studies to date have adjusted for this in the PE-self injurious behaviour association [24, 29]. Finally, personality traits such as impulsivity and reward sensitivity have associations with NSSI and suicide attempts [30, 31], and have

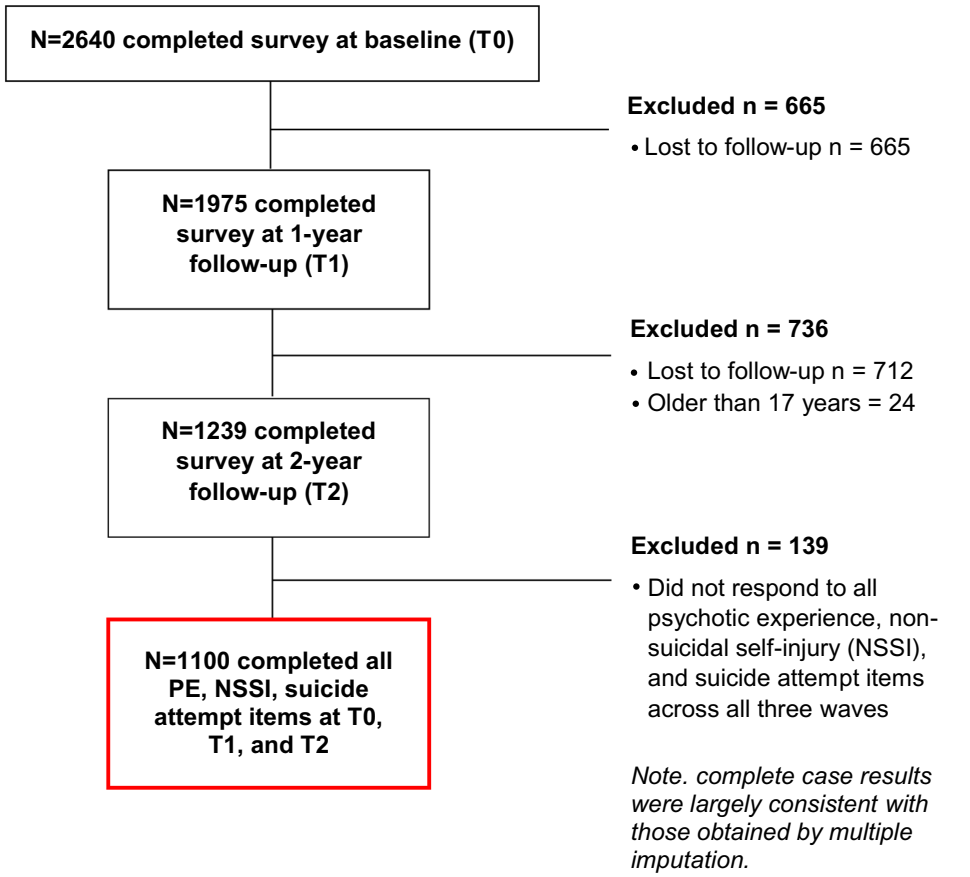

Fig. 1 Flow chart of participants in longitudinal cohort study

been identified as key third variables in the PE–NSSI [32] but not the PE-suicide attempt relationship [33].

We had the opportunity to address our study aims using a prospective longitudinal study of Australian adolescents from whom data were collected at three time points over 2 years. Specifically, we aimed to examine: (1) are baseline PE subtypes associated with future NSSI and suicide attempts over 24 months, and (2) what are the mediators of the association between PEs and NSSI/suicide attempts? Based on previous studies, it is hypothesised that mental health problems (psychological distress, mental disorders and low self-esteem) and exposure to traumatic events such as bullying will be key mediating factors of the PE-NSSI and PE-suicide attempt association.

Methods

Sample, attrition, and missing data

Participants were drawn from the HEALing Project (Helping to Enhance Adolescent Living), a longitudinal cohort study (three time points, 12 months apart) of Australian adolescents aged 12–17 years, previously described in detail elsewhere [6, 34]. The study was approved by Monash University and The University of Queensland Human Research Ethics Committees, with approval also obtained from relevant Catholic Education Archdioceses. Consent was provided by school principals, parents, and students. An information sheet and consent form were sent home to parents of 14,841 students from 41 secondary schools (23 Catholic, 18 independent), of which 3119 (21.0%) were returned, a participation rate consistent with previous Australian school-based studies of adolescents [35–37]. Of those with parental consent, 2640 (84.6%) students completed the survey at baseline (T0). Of these, 1975 (74.8%) completed the survey at 1-year follow-up (T1), and 1263 (47.8%) completed data at all three waves (T0–T2). Twenty-four participants were excluded because they were older than 17 years at one data collection point (T0 and/or T1 and/or T2), leaving a sample of 1239. See Fig. 1 for study flow chart.

Adolescents lost to follow-up (LTF; $n = 1377$, either at T1 [$n = 665$] or T2 [$n = 712$]; 52.2% of total sample) were older, more likely to be male, report PEs at baseline, and report having engaged in NSSI or suicide attempts at baseline. They were also more likely to report psychological

distress, as well as score lower on the Emotion Regulation Questionniare (ERQ) Cognitive Reappraisal subscale and Behavioural Inhibition System (BIS) subscale, and score higher on Behavioural Activation System (BAS) Drive and Fun Seeking subscales (study variables described in detail below). All other variables were not associated with LTF (see Online Resource 1).

In terms of missing data (360 of 1239 participants), 139 participants did not respond to all key items (i.e. PEs, NSSI, suicide attempts) at baseline, T1 and T2, and another 221 did not respond to all mediating variable items. For all analyses, a final sample of $n = 1100$ was used, where participants had responded to all PE, NSSI, and suicide attempt items at all three time points (T0–T2)[1] (see Fig. 1; study flow chart). The exception was the mediation analyses (i.e. Aim 2 analyses), where we instead took the approach of pairwise deletion to handle missing data (sample size range = 1051–1211). The ten mediating variables of interest (see variables below) were incorporated for only one of the study's aims, and too many cases would have been lost if listwise deletion (or complete case analysis) was used.

Key variables

Psychotic experiences PEs were captured using the revised version of The Diagnostic Interview Schedule for Children (DISC-R [38]) Schizophrenia Section, including: lifetime auditory hallucinatory experiences (HEs) ('Have you ever heard voices other people cannot hear?'), and three delusional experiences (DEs) of thoughts being read ('Have other people ever read your thoughts?'), receiving special messages ('Have you ever had messages sent just to you through the television or radio?'), and feeling spied upon ('Have you ever thought that people are following you or spying on you?'). Participants responded to each item as either 'no', 'yes, likely' or 'yes, definitely'. These four items have been used to screen for PEs in adolescents [14, 39] and have previously shown high concurrent validity with clinician-rated psychotic symptoms among adolescents, particularly hallucinatory DISC items [40]. Participants in the HEALing study were classified as endorsing PEs at baseline (T0) if they responded 'yes, definitely' to relevant DISC-R items. A 'no' response was classified if participants responded either 'no' or 'yes, likely', as consistent with previous studies [34]. Incident PEs at 1- (or 2-year) follow-up were coded if participants responded 'no' at T0, but 'yes, definitely' at T1 (or T2).

NSSI and suicide attempts NSSI and suicide attempts were assessed using the Self-Harm Behaviour Questionnaire [41]. NSSI was assessed using the item 'Have you ever hurt yourself on purpose?' (yes or no); which was preceded by the definition of 'hurting yourself on purpose without trying to die'.[2] Incident NSSI 1 year later was coded if participants responded 'no' at T0 but 'yes' at T1, and incident NSSI 2 years later if participants responded 'no' at T0 and T1, but 'yes' at T2. Suicide attempts were assessed using the item 'Did you ever try to end your life?' (yes or no). Incident attempted suicide at 1- and 2-year follow-up were coded the same way as NSSI variables.

Potential mediators of interest

The choice of potentially mediating variables was guided by the wider literature, a systematic review of confounding and mediating factors of the PE-self injurious behaviour association [18], as well as by a previous cross-sectional study with adolescents [4] which examined the individual contribution of several different clinical and psychosocial variables to the PE-NSSI/suicide attempt relationship. This comprehensive analysis found depression, psychological distress, bullying and self-esteem were key third variables in PE-NSSI and PE-suicide attempt associations. Variables such as parental mental illness, disordered eating behaviour, and social isolation had negligible effects in nearly all PE-NSSI and PE-suicide attempt models [4] and therefore, their role was not considered in the current study.

Psychological distress Psychological distress was categorised using the General Health Questionnaire (GHQ-12) clinical cut-off. The GHQ-12 is a self-report screening measure extensively used to assess psychological distress over the past few weeks [42]. Although originally developed for adult populations, the GHQ-12 has subsequently been validated among adolescents [43]. Participants were classified according to sex-stratified clinical cut-offs previously reported in an Australian adolescent sample [44]. Males were classified as experiencing psychological distress if they scored ≥ 13, and females were classified if they scored ≥ 18.

Self-reported diagnosis of mental disorders Self-reported mental disorder diagnosis was based on responses to the item 'Has a doctor ever told you that you have an emotional or behavioural problem?' (yes or no). To better establish temporal relationships, incident mental disorders at T1 were coded if participants responded 'no' at baseline but 'yes' at 1-year follow-up (T1) (see 'Statistical analysis' section for more details) . Of those participants who reported onset of a

[1] Complete case and imputed data were largely consistent, producing similar parameter estimates for all analyses. Complete case data were reported in the results section.

[2] This item was further revised to include only direct self-injury methods as based on participant qualitative data (e.g. cutting, hitting, scratching).

mental disorder at T1 (6.7%, 95% CI 5.2–8.1), the most commonly reported diagnoses were depression ($n = 29$, 39.7%) and anxiety ($n = 36$, 49.3%; these were not mutually exclusive). No participant at T1 (or any other study time point) reported being diagnosed with schizophrenia or psychosis.

Self-esteem The Rosenberg Self-Esteem Scale [45] is a widely used self-report instrument for measuring trait self-esteem. It is a 10-item Likert scale measuring both positive and negative feelings about the self. The scale has shown acceptable psychometric properties in adolescent samples [46], with satisfactory Cronbach's alphas (0.89) in the current sample [47].

Traumatic life events in the past 12 months Several longitudinal studies have shown evidence of a bidirectional relationship where PEs predict subsequent traumatic events involving interpersonal harm (e.g. bullying, physical/sexual victimisation) and vice versa, even after adjustment for confounders [23, 48, 49]. Considering this, variables such as bullying and sexual assault should be treated as potentially mediating variables of the PE-NSSI and PE-suicide attempt associations. In the current study, a recent traumatic life event was coded if participants responded 'yes within the past 12 months' at T1 on the Adolescent Life Events Scale (ALES [50]; see Online Resource 2) to any of the following: been bullied at school, seriously physically abused, or forced to engage in sexual activities. In addition to these traumatic events with intent to harm, two additional ALES items with special consideration were included which pertain to recent (past 12 month) exposure to friend/family self-harm or suicide, considering the known phenomenon of social/familial transmission of self-harm and suicide in young people [51]. Supplementary analyses were conducted with and without self-harm/suicide exposure included in the traumatic life event variable. See Online Resource 2 for more details on the ALES measure and traumatic events of interest for this study.

Emotion regulation The Emotion Regulation Questionnaire (ERQ [52]) is a 10-item, 7-point Likert scale used to assess individual differences in the habitual use of two emotion regulation strategies: Cognitive Reappraisal[3] (6 items) and Expressive Suppression (4 items). Both subscales have shown acceptable psychometric properties in adolescent samples [52, 54].

Behavioural Inhibition and Activation (BIS/BAS) Scales Gray [55] proposed that personality traits are influenced by two fundamental motivational systems: the Behavioural Inhibition System (BIS) and Behavioural Activation System (BAS). Both systems have been implicated in NSSI and suicide attempts [56, 57]. The BIS/BAS scale [58] is a 24-item Likert scale assessing dispositional behavioural inhibition and behavioural activation, including a global BIS score (7 items) and three separate BAS scores: Drive (4 items), Fun Seeking (4 items), and Reward Responsiveness (5 items). The BIS subscale correlates with measures of susceptibility to punishment and harm avoidance, while the BAS subscales correlate with measures of reward seeking and impulsivity [56]. All BIS/BAS subscales have shown sound psychometric properties in this sample (Cronbach's alphas ≥ 0.64 [59]).

[3] The evidence favours reappraisal as a strategy for regulating emotions as opposed to suppression [53].

Statistical analysis

All analyses were conducted using Stata/IC 14.

Preparatory analyses Associations between third variables of interest were explored (age, gender, substance use, psychological distress, mental disorders, self-esteem, traumatic life events, emotion regulation scales, behavioural inhibition/activation scales), where no correlation coefficient was above 0.5, indicating these were relatively distinct constructs. There was no multicollinearity as indicated by a variance inflation factor (VIF) of < 3.0 for all variables [60]. NSSI and suicide attempts were modelled separately in this study.

Regression modelling To address Aim 1, logistic regressions were used to examine the total effect of baseline PEs on incident NSSI and incident suicide attempts at T1 and T2; as well as to examine the total effect of T1 PEs on incident NSSI/suicide attempts at T2.

To address Aim 2 of the study (i.e. explanatory role of third variables), the direct and indirect effects of baseline PEs on incident NSSI/suicide attempts at T2 were explored using the Generalised Structural Equation Modelling (GSEM) function. Potential mediators of interest included: psychological distress; self-reported diagnosis of mental disorders; self-esteem; emotion regulation (ERQ Cognitive Reappraisal and Expressive Suppression subscales); recent traumatic life events; and BIS/BAS subscales. For all these mediating variables, information collected at 1-year follow-up (T1) was used, to better establish temporal relationships between: PEs (captured at T0/baseline) → mediating variable/s (captured at T1/1-year follow-up) → incident self-injurious outcomes (captured at T2/2-year follow-up). Example PE-NSSI and PE-suicide attempt mediation pathways are outlined in Fig. 2, with psychological distress as the example mediating variable. These same pathways were investigated for all other potentially mediating variables (individually, as well as in a combined, parallel mediation model), for each PE subtype. For direct and indirect effects, we drew 1000 bootstrap samples to generate 95% bias-corrected confidence intervals [61, 62]. If the 95% bias-corrected confidence interval (BC 95% CI) of the indirect effect did not include zero, it was considered statistically significant mediation at the 5% level.

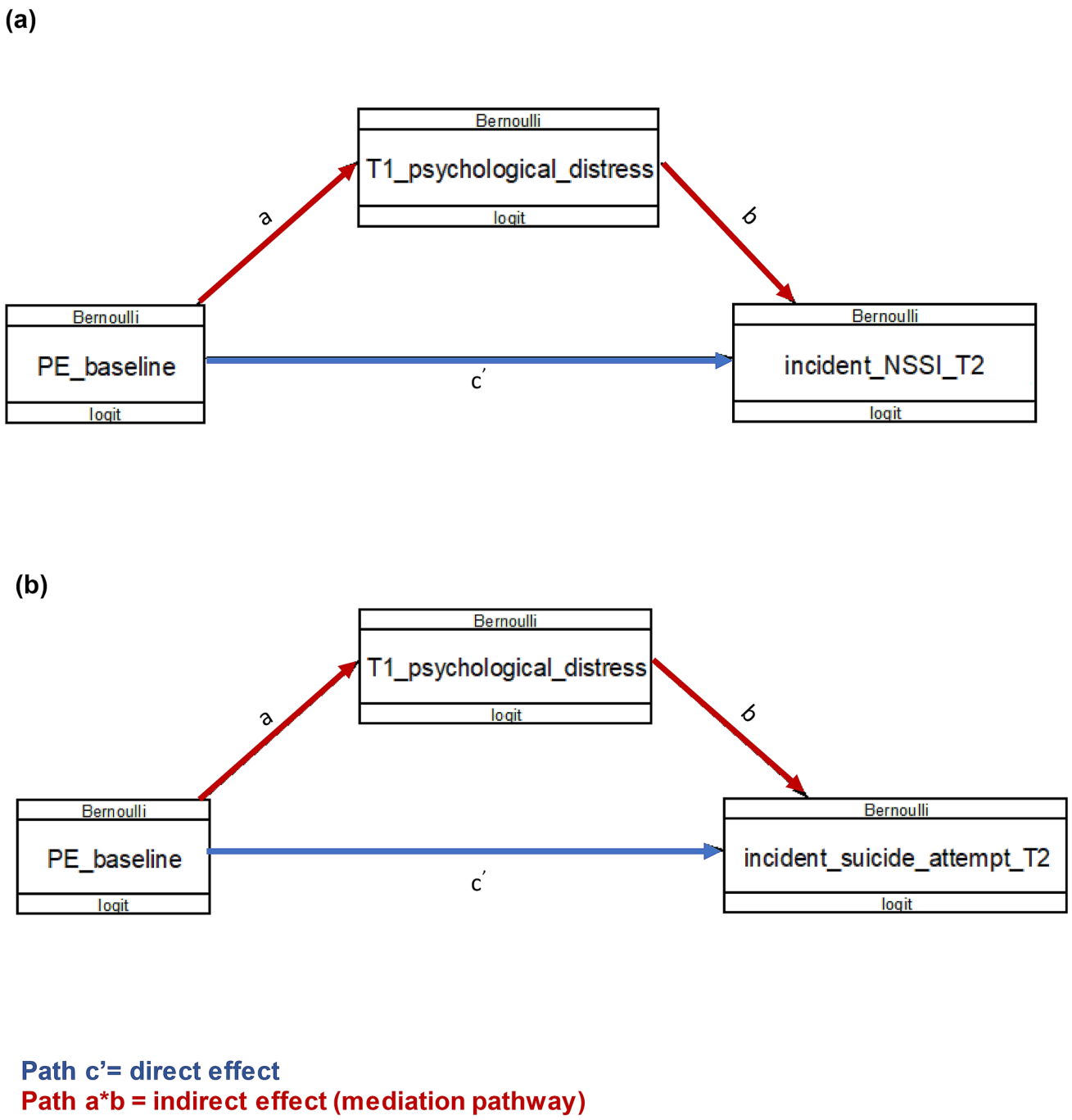

Fig. 2 Psychotic experience (PE)-non-suicidal self-injury (NSSI) (**a**) and PE-suicide attempt (**b**) mediation models to be investigated for Aim 2, using T1 psychological distress (i.e. at or above GHQ-12 clinical cut-off) as an example mediating variable

It is optimal to use a three-wave design to test for mediation [63]. However, considering the large amount of attrition across our three waves (52.2% of total sample), supplementary mediation models were conducted using only the first 2 waves of data; where only 25.2% of the sample was LTF. To achieve this, mediation models followed the two-wave approach of MacKinnon and colleagues [61, 64] which takes advantage of the temporal lag and longitudinal regression for both links in the proposed causal chain. See Online Resource 3 for further details.

Confounders Age (in years) and sex of participants were incorporated as confounders in all analyses. In addition, lifetime substance use (cannabis and other illicit substances) was also included as a confounder considering we were not able to separate out PEs occurring under the influence of alcohol or drugs [18]. Drug-related PEs can be differentiated

Table 1 Psychotic experiences at baseline (T0), and incident psychotic experiences between baseline and 1-year follow-up (T1), and between 1-year and 2-year follow-up (T2) ($n = 1100$)

	Baseline			Baseline → T1 (incident PE)			T1 → T2 (incident PE)		
	n	%	95% CI	*n*	%	95% CI	*n*	%	95% CI
Any PE	219	19.9	17.4–22.3	79	7.2	5.6–8.8	53	4.8	3.6–6.2
Auditory HEs	64	5.8	4.5–7.2	32	2.9	2.0–4.0	18	1.6	0.9–2.4
Thoughts read	84	7.6	6.1–9.2	36	3.3	2.2–4.4	29	2.6	1.7–3.6
Special messages	64	5.8	4.5–7.3	26	2.4	1.5–3.3	15	1.4	0.7–2.0
Spied upon	101	9.2	7.5–10.8	55	5.0	3.8–6.4	39	3.5	2.5–4.7

95% CI 95% confidence interval, *PE* any psychotic experience, i.e., auditory hallucinatory experiences, thoughts read, special messages received, or spied-upon, *HEs* auditory hallucinatory experiences

from non-drug-related PEs in terms of a person's level of functioning and were found to not be related to suicidal behaviour [65].

Results

Demographic characteristics, PEs and NSSI/suicide attempts

There were 1100 participants with complete data collected for all PE, NSSI, and suicide attempt items at baseline (T0), 1-year (T1), and 2-year follow-up (T2). At baseline, their mean age was 13.8 (SE = 0.03), and 75.9% were female. Table 1 shows endorsement of PEs, with 19.9% (95% CI 17.4–22.3) of the sample endorsing any PE at T0, 7.2% reporting incident PEs at T1, and 4.8% reporting incident PEs at T2.

Of the total sample, 93 (8.5%; 95% CI 6.8–10.1) reported NSSI at baseline, and 12 (1.1%; 95% CI 0.5–1.7) reported attempting suicide prior to baseline assessment. In terms of incident NSSI/suicide attempts between baseline and T1, 61 (5.5%, 95% CI 4.2–7.0) participants reported engaging in NSSI, and 9 (0.8%, 95% CI 0.3–1.4) reported incident suicide attempts. In terms of incident NSSI/suicide attempts between T1 and T2, 66 (6.0%, 95% CI 4.6–7.3) participants reported engaging in NSSI, and 19 (1.7%, 95% CI 1.0–2.6) attempted suicide for the first time.

Aim 1: associations between baseline PEs and incident NSSI/suicide attempts

As seen in Table 2, any PE at baseline was associated with NSSI (OR range = 1.78–2.24) and suicide attempts (OR = 2.19) in the following 1–2 years. However, when broken down by subtype, auditory HEs were the only subtype associated with both incident NSSI and suicide attempts, across both time points (except for T1 NSSI). There were wide confidence intervals, however, around estimates of the other PE subtypes (see Table 2).

Aim 2: mediators of the PE-NSSI and PE-suicide attempt associations

Considering the above, mediation analyses focused on baseline auditory HEs as the independent variable of interest (mediators of the other PE subtypes were also explored in supplementary analyses, see pg. 12).

Mediators of the PE-NSSI association In terms of NSSI, the direct effect of auditory HEs was significant ($p < 0.05$) in mental disorder, ERQ expressive suppression, and BAS subscale models; auditory HEs' direct effect was non-significant in all other NSSI models. We found the auditory HE-NSSI association was significantly mediated by psychological distress ($b = 0.60$, SE = 0.33, BC 95% CI 0.08–1.39), low self-esteem ($b = 0.29$, SE = 0.11, BC 95% CI 0.12–0.54), recent traumatic life events ($b = 1.03$, SE = 0.42, BC 95% CI 0.34–1.98), and high BIS scores ($b = 0.12$, SE = 0.06, BC 95% CI 0.02–0.28) (see Online Resource 4).

Mediators of the PE-suicide attempt association The direct effect of auditory HEs was not significant in any of the suicide attempt models. We found the auditory HE-suicide attempt association was significantly mediated by distress ($b = 1.01$, SE = 0.56, BC 95% CI 0.16–2.52), low self-esteem ($b = 0.49$, SE = 0.20, BC 95% CI 0.18–0.97), recent traumatic life events ($b = 1.09$, SE = 0.66, BC 95% CI 0.20–2.84), and low ERQ cognitive reappraisal ($b = 0.18$, SE = 0.14, BC 95% CI 0.001–0.62). Mental disorders, ERQ expressive suppression, and most BIS/BAS scales were not significant mediators of the hallucinatory-NSSI nor -suicide attempt relationship; nor did these variables have significant direct effects, except for mental disorders and BAS(reward subscale) in relation to incident suicide attempts (see Online Resource 4).

Parallel mediation models When all key mediating variables (i.e. significant, single mediators) were included simultaneously in the same model (see Fig. 3 for

Table 2 Association between psychotic experiences and incident non-suicidal self-injury (NSSI) and suicide attempts at T1 and T2, unadjusted and adjusted for confounders ($n = 1100$)

Independent variable: PE at baseline	Incident NSSI at 1-year follow-up								Incident NSSI at 2-year follow-up							
	No ($n = 1039$)		Yes ($n = 61$)		Unadjusted		Model 1[a]		No ($n = 1034$)		Yes ($n = 66$)		Unadjusted		Model 1[a]	
	n	%	*n*	%	OR[b]	95% CI	OR[b]	95% CI	*n*	%	*n*	%	OR[b]	95% CI	OR[b]	95% CI
Any PE (+)	202	92.2	17	7.8	**1.73**	**1.01–2.97**	**1.78**	**1.03–3.07**	203	92.7	16	7.3	1.31	0.73–2.35	1.34	0.75–2.41
Any PE (−)	837	95.0	44	5.0	Ref	–	Ref	–	831	94.3	50	5.7	Ref	–	Ref	–
Auditory HEs (+)	60	93.7	4	6.3	1.04	0.37–2.94	1.11	0.39–3.18	57	89.1	7	10.9	**2.22**	**1.02–4.83**	**2.36**	**1.07–5.19**
Auditory HEs (−)	978	94.4	58	5.6	Ref	–	Ref	–	977	94.3	59	5.7	Ref	–	Ref	–
Thoughts read (+)	76	90.5	8	9.5	1.91	0.88–4.17	1.89	0.87–4.15	76	90.5	8	9.5	1.74	0.80–3.78	1.72	0.79–3.75
Thoughts read (−)	963	94.8	53	5.2	Ref	–	Ref	–	958	94.3	58	5.7	Ref	–	Ref	–
Special messages (+)	60	93.7	4	6.3	1.15	0.40–3.26	1.19	0.41–3.39	61	95.3	3	4.7	0.76	0.23–2.49	0.78	0.24–2.57
Special messages (−)	979	94.5	57	5.5	Ref	–	Ref	–	973	93.9	63	6.1	Ref	–	Ref	–
Spied upon (+)	92	91.1	9	8.9	1.78	0.85–3.73	1.90	0.90–3.99	93	92.1	8	7.9	1.40	0.65–3.01	1.42	0.65–3.07
Spied upon (−)	947	94.8	52	5.2	Ref	–	Ref	–	941	94.2	58	5.8	Ref	–	Ref	–
Independent variable: PE at baseline	Incident suicide attempts at 1-year follow-up								Incident suicide attempts at 2-year follow-up							
	No ($n = 1091$)		Yes ($n = 9$)		Unadjusted		Model 1[a]		No ($n = 1081$)		Yes ($n = 19$)		Unadjusted		Model 1[a]	
	n	%	*n*	%	OR[b]	95% CI	OR[b]	95% CI	*n*	%	*n*	%	OR[b]	95% CI	OR[b]	95% CI
Any PE (+)	215	98.2	4	1.8	3.26	0.87–12.24	3.31	0.88–12.49	214	97.7	5	2.3	1.45	0.52–4.06	1.53	0.54–4.31
Any PE (−)	876	99.4	5	0.6	Ref	–	Ref	–	867	98.4	14	1.6	Ref	–	Ref	–
Auditory HEs (+)	60	93.7	4	6.3	**13.75**	**3.60–52.52**	**14.36**	**3.67–56.17**	62	96.9	2	3.1	1.93	0.44–8.56	2.25	0.50–10.06
Auditory HEs (−)	1031	99.5	5	0.5	Ref	–	Ref	–	1019	98.4	17	1.6	Ref	–	Ref	–
Thoughts read (+)	83	98.8	1	1.2	1.52	0.19–12.28	1.51	0.19–12.26	83	98.8	1	1.2	0.67	0.09–5.07	0.65	0.09–4.97
Thoughts read (−)	1008	99.2	8	0.8	Ref	–	Ref	–	998	98.2	18	1.8	Ref	–	Ref	–
Special messages (+)	64	100	0	0.0	–	–	–	–	61	95.3	3	4.7	3.14	0.89–11.05	3.34	0.94–11.82
Special messages (−)	1027	99.1	9	0.9	–	–	–	–	1020	98.5	16	1.5	Ref	–	Ref	–
Spied upon (+)	99	98.0	2	2.0	2.86	0.59–13.97	2.85	0.58–14.06	98	97.0	3	3.0	1.88	0.54–6.57	1.99	0.57–6.99
Spied upon (−)	992	99.3	7	0.7	Ref	–	Ref	–	983	98.4	16	1.6	Ref	–	Ref	–
Independent variable: PE at T1	Incident NSSI at 2-year follow-up								Incident suicide attempts at 2-year follow-up							
	No ($n = 1034$)		Yes ($n = 66$)		Unadjusted		Model 1[a]		No ($n = 1081$)		Yes ($n = 19$)		Unadjusted		Model 1[a]	
	n	%	*n*	%	OR[c]	95% CI	OR[c]	95% CI	*n*	%	*n*	%	OR[c]	95% CI	OR[c]	95% CI
Any PE (+)	139	89.1	17	10.9	**2.23**	**1.25–3.99**	**2.24**	**1.25–4.00**	151	96.8	5	3.2	**2.20**	**1.05–6.20**	**2.19**	**1.02–6.21**
Any PE (−)	895	94.8	49	5.2	Ref	–	Ref	–	930	98.5	14	1.5	Ref	–	Ref	–
Auditory HEs (+)	45	86.5	7	13.5	**2.61**	**1.13–6.03**	**2.58**	**1.10–6.02**	49	94.2	3	5.8	**3.95**	**1.11–14.01**	**4.46**	**1.24–16.05**
Auditory HEs (−)	989	94.4	59	5.6	Ref	–	Ref	–	1032	98.5	16	1.5	Ref	–	Ref	–

Table 2 (continued)

Independent variable: PE at T1	Incident NSSI at 2-year follow-up							Incident suicide attempts at 2-year follow-up						
	No ($n = 1034$)		Yes ($n = 66$)		Unadjusted		Model 1[a]	No ($n = 1081$)		Yes ($n = 19$)		Unadjusted		Model 1[a]
	n	%	*n*	%	OR[c]	95% CI	OR[c] 95% CI	*n*	%	*n*	%	OR[c]	95% CI	OR[c] 95% CI
Thoughts read (+)	48	87.3	7	12.7	**2.44**	**1.06–5.62**	**2.52** **1.08–5.85**	53	96.4	2	3.6	2.28	0.51–10.14	2.22 0.50–9.90
Thoughts read (−)	986	94.4	59	5.6	Ref	–	Ref –	1028	98.4	17	1.6	Ref	–	Ref –
Special messages (+)	35	97.2	1	2.8	0.44	0.06–3.26	0.42 0.06–3.14	35	97.2	1	2.8	1.66	0.22–12.79	1.68 0.22–12.98
Special messages (−)	999	93.9	65	6.1	Ref	–	Ref –	1046	98.3	18	1.7	Ref	–	Ref –
Spied upon (+)	71	85.5	12	14.5	**3.01**	**1.54–5.89**	**2.94** **1.50–5.77**	80	96.4	3	3.6	2.35	0.67–8.22	2.33 0.66–8.19
Spied upon (−)	963	94.7	54	5.3	Ref	–	Ref –	1001	98.4	16	1.6	Ref	–	Ref –

Bold indicates significant odds ratio ($p < 0.05$)

OR odds ratio, *95% CI 95%* confidence interval, *PE* any psychotic experience, i.e., auditory hallucinatory experiences, thoughts read, special messages received or spied-upon, *HEs* auditory hallucinatory experiences, *NSSI* non-suicidal self-injury, *Ref* reference group

[a]Model 1: adjusted for sociodemographics (age, sex) and lifetime substance use (cannabis and other illicit substances)

[b]Odds ratio comparing the groups with (+) and without (−) psychotic experiences at baseline (e.g., for the 'any PE' logistic regression, the reference group is no endorsement of any psychotic experience at baseline)

[c]Odds ratio comparing the groups with (+) and without (−) psychotic experiences at T1 or 1-year follow-up (e.g., for the 'any PE' logistic regression, the reference group is no endorsement of any psychotic experience at 1-year follow-up). Note, this is capturing any psychotic experience endorsed at T1, not just 'incident PEs' at T1

parallel mediation models), traumatic life events in the past 12 months (as reported at T1) was the remaining significant mediator of the hallucinatory-NSSI ($b = 0.83$, SE = 0.37, BC 95% CI 0.17–1.72; *Pathway a*: OR = 2.08, 95% CI 1.22–3.55, *Pathway b*: OR = 3.10, 95% CI 1.78–5.40) and hallucinatory-suicide attempt relationship ($b = 0.62$, SE = 0.46, 95% CI 0.28–1.53); although the latter was no longer significant when confounders and bias-corrected bootstrapping were applied ($b = 0.59$, SE = 0.57, BC 95% CI − 0.12 to 2.12; *Pathway a*: OR = 2.21, 95% CI 1.30–3.74, *Pathway b*: OR = 2.13, 95% CI 0.76–5.92). In supplementary analyses (data not shown) where the two self-harm/suicide exposure variables were removed, NSSI findings remained consistent. Recent traumatic life events remained a significant mediator in both single and parallel HE-NSSI mediation models when only bullying, sexual assault, and physical abuse were included. This was not the case for suicide attempts, where recent traumatic events became a non-significant mediator (in both single and parallel mediation models) when self-harm/suicide exposure variables were removed. Of note, no single traumatic life event was a significant mediator of any of the associations.

Supplementary mediation models Using MacKinnon et al.'s (2008, 2009) two-wave mediation approach, we found largely consistent results with our three-wave mediation models (see Online Resource 3). Using the first 2 waves of data, we found psychological distress, self-esteem, and recent traumatic life events were all significant single mediators of the association between baseline auditory HEs and incident NSSI/suicide attempts at T1; except for traumatic life events, which was not a significant single mediator of the HE-incident suicide attempt association. In addition, BIS scores were not a significant mediator of the HE-NSSI association; whereas both ERQ cognitive reappraisal and expressive suppression significantly mediated the HE-suicide attempt association. All other potentially mediating pathways were non-significant, as consistent with three-wave, single mediation results. Parallel mediation models using the first 2 waves of data found for NSSI models, recent traumatic events and low-self-esteem remained significant mediators of the PE-NSSI association. For suicide attempt models, psychological distress remained a significant mediator of the PE-suicide attempt association.

In terms of the other PE subtypes, their three-wave mediation findings were largely inconsistent with auditory HEs results (data not shown). There were no significant direct or indirect (i.e. mediating) pathways of the thoughts read-NSSI/suicide attempt association. For both special messages and feeling spied-upon, psychological distress and low self-esteem were significant single mediators of the -NSSI and -suicide attempt associations; however, in the parallel mediation models, there were no significant mediating pathways.

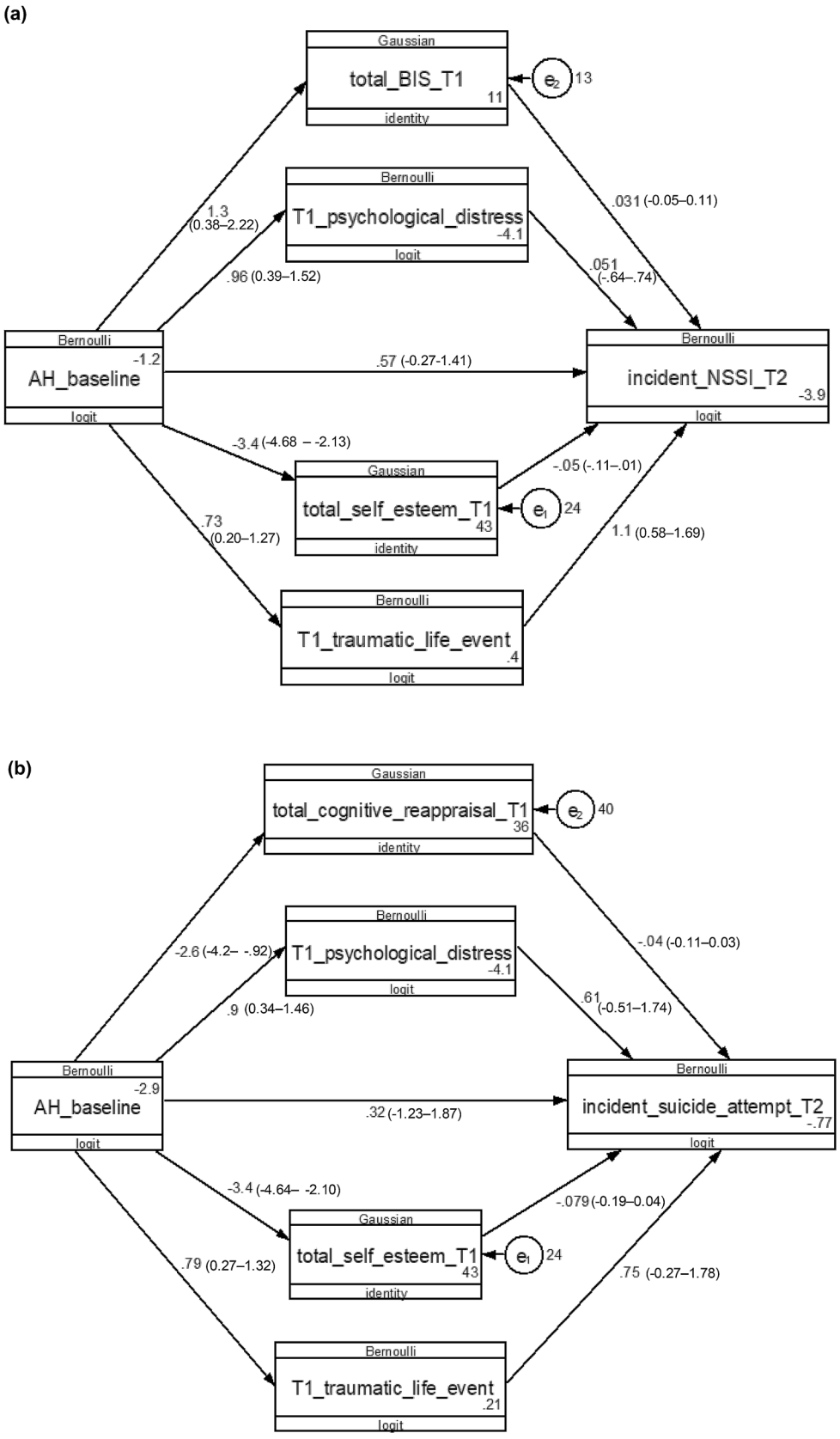

Fig. 3 **a** Parallel mediation model of key mediating variables in the auditory hallucinatory experience (HE)-non-suicidal self-injury (NSSI) association ($n = 1051$) and **b** parallel mediation model of key mediating variables in the auditory HE-suicide attempt association ($n = 1087$). Unstandardised effects are reported; 95% confidence intervals are reported in brackets next to estimates; confounders (age, sex, substance use) not shown; *AH_baseline* auditory hallucinatory experiences at baseline; *total_BIS_T1* total Behavioural Inhibition scores at 1-year follow-up (T1). In terms of recent (T1) traumatic life events, of the participants reporting both baseline auditory hallucinatory experiences and incident self-injurious behaviour at T2, 33.3% reported being bullied, 22.2% reported being sexual assaulted, 22.2% reported close friends or family had attempted suicide or deliberately harmed themselves, and 11.1% reported being physically abused at T1

Discussion

This is the first study, to our knowledge, to investigate both the PE-NSSI and PE-suicide attempt association, and their relevant mediators, across three waves of data. Of all the PE subtypes, auditory HEs were consistently associated with incident NSSI and suicide attempts at the 1- and 2-year follow-up; although some estimates had wide confidence intervals indicating a lack of precision in the estimates, and a potential type II error (see Table 2). This is consistent with our previous results using a nationally representative sample of Australian adolescents [4], as well as the wider literature supporting the important and specific role of hallucinatory experiences in self-harm and suicidal behaviour [12, 16, 66].

Auditory HEs were indirectly associated with future NSSI via psychological distress, low self-esteem, recent traumatic life events, and high BIS scores. Similarly, the auditory HE-suicide attempt association was significantly mediated by distress, self-esteem, recent traumatic life events, and low ERQ cognitive reappraisal. These findings were supported by supplementary two-wave mediation analyses. These results are consistent with the rationale that experiencing PEs produces emotional and behavioural responses (e.g. high levels of distress and negative self-evaluation) that increases the likelihood of self-harming or attempting suicide [66–69]. Findings related to low cognitive reappraisal in suicide attempt models, i.e. a tendency to escape or avoid one's own emotions [52, 70], and high BIS scores in NSSI models, i.e. a sensitivity to and avoidance of stimuli perceived as threatening or punishing [56, 57, 71] are consistent with the wider literature showing young people with PEs report difficulties with coping skills and emotion regulation [8, 14].

When all key mediating variables were included in parallel mediation models, recent traumatic life events remained a significant mediator of the auditory HE-NSSI association; but not the HE-suicide attempt association, albeit with relatively large point estimates (OR range 2.13–2.21; see Fig. 3b). Recent traumatic life experience was the main mediating variable of the auditory HE-NSSI/suicide attempt association, confirming previous proposals that the relation between these two phenomena is not direct, but rather is explained by traumatic life events, particularly interpersonal events with intent to harm [14, 24, 72, 73]. This HE → traumatic life event → NSSI/suicide attempt pathway has face validity as there is robust evidence for these types of traumatic life events (i.e. bullying, sexual assault) preceding self-harm or a suicide attempt among adolescents [73–76]. Experiencing auditory HEs, which in themselves are distressing [77], and are often characterised by threat-related content [78], could result in (1) a young person being more vulnerable to experiencing traumatic life events (e.g. increased vulnerability to subsequent victimisation, [49]), and/or (2) interpreting negative interactions with others in a more pessimistic/adverse manner and therefore may be more likely to label such experiences as bullying [23, 48]. It should be noted that the traumatic event variable also included exposure to friend or family self-harm/suicide, which was influential of the auditory HE-suicide attempt association (but not the auditory HE-NSSI association). Adolescents with PEs may live in social circumstances where they are more likely to be exposed to a friend or family member's self-harm/suicide [23]. This may affect a young person's suicide risk due to the trauma experienced, as well as via other mechanisms such as social transmission of suicide [51]. The differing psychosocial/environmental mechanisms via which PEs are associated with non-suicidal and suicidal behaviours need to be further considered going forward.

Strengths

This cohort study was the first to investigate PE-NSSI and PE-suicide attempt associations across three waves. Most of the PE literature has not investigated NSSI, a critical but often overlooked self-injurious behaviour which is not a suicide attempt per se, but nevertheless increases the risk of suicide death among adolescents [79, 80]. The choice of mediators was driven by a comprehensive approach; including a previous investigation of the individual contribution of several potential mediators using a nationally representative adolescent sample [4]. There was clear establishment of the temporal sequence of events in the three-wave mediation models. This is not often achieved in mediation analyses, and many previous PE studies do not take baseline NSSI/suicide attempts into account when predicting future self-harm and suicide attempts.

Limitations

The sample size, whilst large ($n = 1100$), was still underpowered for examining low prevalence outcomes such as suicide attempts. This may have resulted in type II errors with true associations being reported as non-significant. Similar to other prospective suicide studies [34] some cell sizes were small, and we recommend caution when interpreting these results. Early child maltreatment could not be investigated using the current dataset, which should be included as a confounder in future studies for a more complete analysis of the PE-self injurious behaviour association. There are well-established links between childhood trauma and auditory HEs [26, 81], and studies have found childhood adversity and recent school life stressors have an interactive (or multiplicative) effect on predicting youth suicidality [82]. Biological and genetic factors were also not included; however, heritability estimates of hallucinations are low [83, 84]

indicating the significance of early trauma and other environmental factors in their occurrence [84].

This was not a nationally representative sample of adolescents and generalisability was limited by the high rate of non-response from parents who did not return consent forms. Also, our sample was largely drawn from Catholic schools. We experienced attrition (52.2% of total sample) where those lost to follow-up reported more PEs, self-injurious behaviour, psychological distress, dysfunctional emotion regulation strategies and less behavioural inhibition at baseline, compared to those not lost to follow-up. However, supplementary mediation analyses using only the first 2 waves of data found largely consistent results with the three-wave mediation models (Online Resource 3). All variables were self-reported, with no clinical assessment, and thus prone to measurement error due to misinterpretation of the question and recall bias. Finally, the focus of this study was on the mediators of the association between PEs and self-injurious behaviour. It is of course plausible that traumatic life events precede auditory HEs which in turn could lead to NSSI/suicide attempts. This was beyond the scope of this study. This would be best investigated using a multi-wave dataset of recent measures of all phenomena (as opposed to lifetime measures at each timepoint), and by using particular modelling approaches such as cross-lagged regression [85], which allows for modelling of bidirectional relationships across multiple timepoints, but which has a strict set of assumptions [85–88].

Clinical implications

The current findings underscore the importance of screening for auditory HEs when assessing a young person's self-harm/suicide risk. Other PE subtypes appear to be of less importance in terms of NSSI/suicide attempt risk, where most were not associated with incident NSSI or suicide attempts, either directly or indirectly; although some estimates had wide confidence intervals (Table 2). Clinical assessment of self-harm and suicide risk in young people with PEs would be further enhanced by asking about interpersonal stressors/traumatic events (e.g. bullied, physical or sexual abuse/assault, family/friend suicide), as well as self-esteem and levels of distress. Empathic inquiry about these with appropriate validation may assist in reducing self-harm and suicide risk. Fostering resilience, self-esteem, healthy emotion regulation and coping strategies, and help seeking behaviour among young people with PEs may assist in preventing self-harm and suicide.

Future research

Considering the limited generalisability, our findings require replication in larger, more representative adolescent samples. Future studies should also focus on investigating the potential influence of hallucinatory characteristics (e.g. voice omnipotence and intent), the explanatory value of self-harm/suicidal theories (e.g. Interpersonal Theory of Suicide) in the auditory HE-self injurious association [34], as well as the dynamic nature of the relationship. Previous studies have shown PEs that are more persistent in nature have more robust associations with NSSI and suicide attempts [7, 89], but this has yet to be investigated across three (or more) waves of data.

Conclusions

Auditory HEs were indirectly associated with future NSSI and suicide attempts via recent traumatic life events (being bullied, physically or sexually abused/assaulted, exposed to friend/family self-harm or suicide), high psychological distress, and low self-esteem, across three waves of data. Other PE subtypes were mostly not associated with incident NSSI/suicide attempts at 1- and 2-year follow-up, either directly or indirectly. By identifying relevant and modifiable targets for youth self-harm/suicide prevention and intervention efforts, this prospective cohort study has high clinical utility for young people with PEs.

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Data availability Data available upon request.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

Ethical standards The study was approved by Monash University and The University of Queensland Human Research Ethics Committees and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Consent was provided by school principals, parents, and students.

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