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ORIGINAL ARTICLE

Picturing self-harm: Investigating flash-forward mental imagery as a proximal and modifiable driver of non-suicidal self-injury

Julie L. Ji PhD[1,2] | **Michael Kyron PhD**[2] | **Lisa Saulsman PhD**[2] | **Rodrigo Becerra PhD**[2] | **Ashleigh Lin PhD**[3] | **Penelope Hasking PhD**[4] | **Emily A. Holmes PhD, DClinPsych**[5]

[1]School of Psychology, University of Plymouth, Plymouth, UK

[2]School of Psychological Science, University of Western Australia, Perth, Western Australia, Australia

[3]School of Population and Global Health, University of Western Australia, Perth, Western Australia, Australia

[4]Curtin enAble Institute, Curtin University, Perth, Western Australia, Australia

[5]Department of Women's and Children's Health, Uppsala University, Uppsala, Sweden

Correspondence
Julie L. Ji, School of Psychology, University of Plymouth, Plymouth PL4 8AA, UK.
Email: julie.ji@plymouth.ac.uk

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Abstract

Objectives: Non-suicidal self-injury (NSSI) is theorized to be reinforced by its emotional consequences. Mental images of NSSI are commonly reported as occurring prior to NSSI. Based on the known functional properties of anticipatory mental imagery as an emotional and motivational amplifier, this study investigated whether NSSI mental imagery constitutes a proximal and dynamic mechanism underpinning NSSI risk.

Method: An intensive ecological momentary assessment (EMA) study was conducted to track the occurrence and characteristics of NSSI mental imagery alongside NSSI urge and behavior in naturalistic settings. A sample of $N = 43$ individuals aged 17 to 24 with a history of repetitive NSSI completed EMA surveys seven times a day for 14 days.

Results: Mental preoccupation in the form of NSSI mental imagery-based flash-forwards to the actions, bodily sensations, and emotional benefits of NSSI was found to occur when NSSI urge was high but not when urge was low. Critically, objective cross-panel analyses showed that higher frequencies of NSSI imagery occurrence predicted greater future NSSI urge and increased likelihood of acting on urge, over and above current urge.

Conclusions: Mental imagery of NSSI is not simply an epiphenomenal by-product of NSSI urge and may constitute a dynamic and proximal novel intervention target.

KEYWORDS

flash-forward mental imagery, motivation, non-suicidal self-injury, self-harm

Non-suicidal self-injury (NSSI) is defined as the deliberate damage to one's own bodily tissue performed without suicidal intention (International Society for the Study of Self-Injury, 2018). NSSI is prevalent amongst young people in Western nations, estimated at 17.2% of adolescents and 13.4% of college-aged young adults (Swannell et al., 2014), with similar trends observed globally (Cheng et al., 2023). Many young people who commence NSSI go on to engage in it repetitively and have difficulty relinquishing it due to NSSI's short-term emotion regulation functions (Andrewes et al., 2017). Specifically, NSSI is negative and positively reinforced by its immediate emotional benefits, including the alleviation of distress, tension, numbness, and the gratification of self-punishment needs, respectively (Fox et al., 2017; Hooley & Franklin, 2018; Nock & Prinstein, 2004). NSSI occurs trans-diagnostically across psychiatric populations (Bentley et al., 2015) as well as community samples (Selby et al., 2012) and is a reliable and leading predictor of future suicidal self-injury (Franklin et al., 2017; Wilkinson et al., 2011).

At present, there are no recommended pharmacological treatments for NSSI, and there is weak evidence for evidence-based psychological treatments (NICE, 2022). Importantly, more than half of those with a history of NSSI do not receive treatment for the behavior in the UK (Liu, 2023). The identification of novel intervention targets to drive scalable treatment innovation for NSSI is therefore a research priority (Dobias et al., 2023). To this end, there is growing consensus that psychological treatment innovation is most effectively and efficiently guided by the identification of proximal and modifiable mechanisms that causally contribute to the development and maintenance of the target phenomenon (Holmes et al., 2018).

Understanding the proximal and dynamic drivers of NSSI urge fluctuation is likely to aid the identification of novel intervention targets. NSSI episodes are triggered by negative affect (Kiekens et al., 2020) and are preceded by thoughts and urges that intensify over time (Himelein-Wachowiak et al., 2022; Miller et al., 2021), typically over a duration of approximately 30 min (Fitzpatrick et al., 2020). Interestingly, while urge intensity is a strong proximal predictor of NSSI behavior (Ammerman et al., 2017; Turner et al., 2019), negative affect (Kiekens et al., 2020) and persistent ideation do not appear to be strong predictors of behavior (Turner et al., 2019). We are only aware of one study that has investigated proximal predictors of NSSI urge. Using a low-intensity ecological momentary assessment (EMA) protocol, Burke et al. (2022) found that although daily levels of drive and reward sensitivity tracked with NSSI urge, it did not predict future changes in NSSI urge, which suggests that it may be a by-product of urge rather than a causal driver of urge.

Mental imagery has been proposed as a possible a novel intervention target for self-injury (Lawrence et al., 2023). Mental imagery refers to internal perceptual experiences without external sensory input (Kosslyn et al., 2001; Pearson et al., 2015). Due to substantial overlaps between perception and mental imagery, imagery-based mental simulations can enable individuals to pre-experience imagined situations in an as-if-real manner (Lang, 1979; Mathews et al., 2013; Moulton & Kosslyn, 2009). Mental imagery can evoke emotional responses (for a review, see Ji et al., 2016) and motivate reward activity engagement (Ji et al., 2021; Renner et al., 2017, 2019). Imagining consumption can also intensify cravings through increasing anticipated reward and feelings of deprivation (May, Kavanagh, & Andrade, 2015). Thus, it is possible that mental imagery of NSSI may amplify NSSI urge, particularly if its content involves flash-forwards to the anticipated experience and its emotional benefits.

Prior research has found that emotionally charged visual or multisensory mental imagery of NSSI behavior is a prevalent feature of NSSI (for a review, see Lawrence et al., 2023), although its relationship to NSSI urge remains unclear. Mental imagery of NSSI is retrospectively reported to occur when the NSSI urge is strong and to depict instruments, actions, and bodily sensations associated with NSSI (Cloos et al., 2020; Hasking et al., 2018; McEvoy et al., 2017). Further, the content of NSSI-related imagery is subjectively perceived to functionally impact NSSI, such that mental imagery relating to NSSI actions, bodily sensations, and emotional benefits was perceived to encourage the individual to act on their urge, whereas imagery content relating to perceived downsides of NSSI was perceived to discourage the individual from acting on their urge (McEvoy et al., 2017). However, to date, there has been no real-time investigation of NSSI-related mental imagery as a proximal predictor of NSSI urges or behaviors.

The present research

This study investigated NSSI-related mental imagery as a possible dynamic and proximal driver of NSSI urge and behavior using an intensive ecological momentary assessment (EMA) protocol involving seven prompts per day across 14 days. Based on prior research on mental imagery in NSSI and the known basic properties of mental imagery as a motivator of goal-directed behavior, the overarching hypothesis is that repeatedly imagining NSSI behavior functionally contributes to the intensification of NSSI urge because it involves "flash-forward" mental simulations of the behavior, enabling individuals to pre-experience its short-term emotional benefits.

The overarching hypothesis generates the prediction that the occurrence of NSSI-related mental imagery would dynamically track with NSSI urge, occurring in high frequencies when urge is high and in low frequencies when urge is low (H1). Relatedly, it was hypothesized that the content of NSSI-related mental imagery would predominantly depict the actions and bodily sensations involved in carrying out NSSI, as well as its subsequent emotional benefits (H2). Importantly, if repeatedly imagining NSSI does functionally contribute to the intensification of NSSI urge, then the occurrence of NSSI imagery should predict increases in urge over time, over and above the effects of existing urge (H3a). However, if NSSI imagery is simply an epiphenomenal by-product of urge, then the occurrence of NSSI imagery would not prospectively predict urge over and above existing urge (H3b).

Further, we explored whether NSSI imagery can proximally predict the likelihood of whether NSSI urge is acted upon, over and above the effects of existing urge. On one hand, it is possible that NSSI imagery motivates NSSI behavior only via its impact on urge, and therefore would not predict the likelihood of NSSI behavior over and above urge. On the other hand, mental imagery is known to facilitate action execution (Bennet & Reiner, 2022) and influence judgments of event plausibility (Szpunar & Schacter, 2013), and is theoretically implicated in the volitional stage of suicidal self-injury (O'Connor & Kirtley, 2018), so it is possible that NSSI-imagery may predict NSSI behavior over and above urge[1].

While verbal–linguistic thoughts relating to NSSI were not the primary focus of the present study, the frequency of NSSI-related verbal thoughts was also assessed to ensure participants continued to differentiate mental imagery from verbal–linguistic cognition.

METHOD

Participants

A total of $N = 53$ participants in Perth, Western Australia, were recruited into the study. Study inclusion criteria were: (a) age between 17 and 24; (b) self-reported NSSI on ≥5 days in the past year (DSM-5 diagnostic criteria for NSSI disorder; American Psychological Association, 2013); (c) the presence of NSSI ideation in the past month; and (d) no suicide attempts in the past 24 months. Sample size calculation was guided by recommendations for the minimum number of "target" events required for constructing valid prognostic predictive models yielding unbiased and precise estimates is 100 "target events" (Collins et al., 2016). Based on compliance and target event rates from prior research using a similar sample (Kiekens et al., 2020), at least 40 participants were needed to observe a minimum of 100 target events across a 14-day study with 7 prompts per day, at a compliance rate of 70%, assuming that NSSI behavior occurs only in 50% of the sample, on 7.00% of EMA sampling points. Following online screening, the 53 potentially eligible individuals were invited to attend a baseline assessment session, where 6 were found to be ineligible based on suicide risk assessment (see Appendix A in Appendix S1 for suicide risk assessment and safety planning procedures, openness and transparency statement, and baseline assessment measures).

The study was approved by the University of Western Australia Human Research Ethics Review Board (Approval Number: 2021/ET000529).

Baseline session materials

Baseline assessment materials and procedures are reported in full in Appendix B in Appendix S1, and summarized below:

Non-Suicidal self-injury (NSSI) history

Section I of the Inventory of Statements about Self-Injury (ISAS; Klonsky & Glenn, 2009) was used to assess NSSI history.

Anxiety and depression

The Kessler Psychological Distress Scale (K10; Kessler et al., 2002) was used to assess anxiety and depression symptoms. Internal consistency in the present sample was good, *Cronbach's* $\alpha = 0.876$.

Baseline mental imagery tendency

Baseline mental imagery tendency was assessed using the Spontaneous Use of Imagery Scale (SUIS; Reisberg, Pearson, & Kosslyn, 2003). Internal consistency in the present sample was good, *Cronbach's* $\alpha = 0.832$.

Baseline mental imagery ability

Baseline mental imagery ability was assessed using the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). Internal consistency in the present sample was excellent, *Cronbach's* $\alpha = 0.931$. Scores ranged from 16 to 80, with higher scores reflect greater imagery vividness.

Ecological momentary assessment (EMA) protocol

Following the baseline session, participants completed the EMA component of the study via the mobile phone app SEMA3 (Koval et al., 2019). Seven EMA surveys were pushed to participants per day between 9 a.m. and 10.30 p.m., pseudo-randomly every 30–120 min. Participants could also trigger their own EMA surveys if NSSI behavior occurred in between survey prompts. As shown in Table 1, each survey contained four categories of questions: (a) Context (Q1–4: current mood, location, activity, whether alone or not) designed to provide a buffer before the NSSI question; (b) NSSI ideation, urge, behavior, method, and function (Q5–9); (c) NSSI flash-forward Imagery characteristics (Q10–12 & 15–16: frequency, content, vividness, emotional valence, temporal focus); (d) Perceived functional impact of NSSI flash-forward Imagery on NSSI urge and on NSSI behavior (Q13 & 14). To minimize participant burden, participants were asked to report on the direction of functional impact only, that is, whether the NSSI imagery they experienced since the last survey had (1) increased, (2) decreased, or (3) had no impact on their NSSI urge (Q13), and the likelihood of them acting on their urge (Q14). NSSI Imagery Characteristics and Functional Impact questions were only shown if participants reported experiencing NSSI imagery since the last survey. Finally, NSSI Verbal Thought was assessed in terms of Frequency and Emotional Valence. Survey questions were co-designed with members of a lived-experience youth advisory board.

As shown in Figure A in Appendix S1, while questions about context and NSSI urge are about "right now" (T), questions about NSSI cognition pertain to the time between T and T-1.

Analyses approach

Cross-sectional analyses

Hypotheses 1 concerned the cross-sectional relationship between NSSI Imagery Frequency and NSSI Urge, and hypothesis 3 concerned the relationship between NSSI Imagery Frequency and NSSI Imagery Emotional Valence. For comparison purposes, NSSI Verbal Thought Frequency was also included to explore differences between NSSI Imagery and Verbal Thought. As such, two linear mixed effects models (LMMs) were conducted, one for each hypothesis. Each model was fitted with NSSI Cognition Frequency and Cognition Format as fixed effects predictors, Subject as random intercept, and Cognition Format as random slope. LMM models were fitted using the lme4 package (Bates et al., 2015) in R (R Core Team), using Restricted Maximum Likelihood (REML) estimation of parameters to minimize bias for small sample sizes. Effect sizes for fixed effects and fixed and random effects combined are reported in model output tables as Marginal and Condition R^2, respectively. LMM use was deemed appropriate due to moderate Intraclass Correlation (ICC) values for the NSSI Urge model (ICC = 0.250) and the NSSI Cognition Emotional Valence model (ICC = 0.490). Descriptive statistics were sufficient to test Hypothesis 2, thus no statistical analyses were conducted.

Cross-temporal analyses

To test hypothesss 4 and 5, time-lagged associations between NSSI Imagery Frequency, Vividness, and Content and NSSI Urge and Behavior were assessed using dynamic multilevel structural equation modeling (DSEM), fitted using Mplus Version 8.2 (Muthén & Muthén, 2019). Estimates are interpreted with their 95% credibility intervals, i.e., the range within which the 'true' relationship is 95% likely to fall. Mplus uses a Kalman filter to account for missing data, which makes predictions of the next observation based on lagged predictors that are updated based on observed data (McNeish & Hamaker, 2020). DSEM results presented in the current study were standardized, reflecting how many standard deviations the dependent variable increases when the predictor variable increases by one standard deviation. In each model, autoregressive effects have been included to consider inertia of variables over time. The exception to this is NSSI action, which did not exhibit a significant autocorrelation. NSSI action and imagery frequency have been treated as categorical variables in relevant models. Full details of the analyses approach are reported in Appendix D in Appendix S1.

Transparency and openness

The study was not pre-registered, but the study rationale and high-level design were a-priori and peer reviewed as part of grant funding acquisition for the study. Specific components of the study protocol that were a-priori include: (a) sample eligibility criteria; (b) EMA protocol (14-day duration, eight surveys per day were planned, but the actual study deployed seven surveys per day based on consultation with Youth Advisory Panel); (c) sample size;

TABLE 1 Ecological momentary assessment (EMA) survey questions.

Section	Q#	Question label	Question	Response option
Context[a]	1	State Emotion	Q1. "How are you feeling right now?"	100-point VAS scale "-50 Really bad" to "50 Really good"
	2	Location	Q2. "Where are you right now?"	Multiple choice (single response) "My home"; "Friend's/family's home"; "Work/school/uni"; "Car/train/bus"; "Outside"; "Other indoor place"
	3	Activity	Q3. "What were you doing just before this beep?"	Multiple choice (multiple responses) "Nothing"; "Working/studying"; "Doing chores"; "Socializing"; "Leisure – active (sports; going out)"; "Leisure – passive (watching TV; listening to music)"; "Something else"
	4	Alone	Q4. "Are you alone or with others?"	Likert scale (single response) "Alone"; "Not alone but not interacting with others"; "Interacting with others in person"; "Interacting with others online"
NSSI Urge & Behavior	You will now be asked brief questions about deliberately hurting yourself without wanting to die. This will be referred to as "self-harm."			
	5	NSSI Ideation	Q5. "Since the last beep, have you considered self-harming?"	Likert scale (single response) "Not at all"; "A little of the time"; "Some of the time"; "Most of the time"; "The whole time"
	6	NSSI Urge	Q6. "Right now, how strong is the urge to self-harm"	"0 (No urge at all)" – "100 (Extremely strong urge)"
	7	NSSI Behavior	Q7. "Since the last beep, did you self-harm?"	Binary choice "Yes/No"
		IF Q7 response = "Yes"		
	8	NSSI Behavior – Method	Q7.1 "How did you self-harm?"	Multiple choice (multiple responses) "Cut or carved myself"; "Scratched myself"; "Hit myself"; "Burned myself"; "Bit myself"; "Head banging"; "Wound interfering"; "Other method"
	9	NSSI Behavior – Function	Q7.2. "Why did you self-harm?"	Multiple choice (multiple responses) "To stop/gain relief from bad feelings" "To release tension/to relax" "To feel something/stop feeling numb" "To feel in control" "To punish myself" "To get other people to act differently or change" "To stop suicidal thoughts & feelings"

(Continues)

TABLE 1 (Continued)

Section	Q#	Question label	Question	Response option
NSSI flash-forward Imagery	10	NSSI Imagery – Frequency	Q8. "Since the last beep, have you experienced intrusive visualizations (mental images) related to self-harm?"	Likert scale (single response) "Not at all"; "A little of the time"; "Some of the time"; "Most of the time"; "The whole time"
	IF Q10 response ≠ "Not at all"			
	11	NSSI Imagery – Content	Q8.1 "What were these intrusive images about"	Multiple choice (multiple responses) "The release/relief of hurting myself" "The downsides of hurting myself" "How I would carry out the act of hurting myself" "Other"
	12	NSSI Imagery – Vividness	Q8.2 "How vivid/compelling were the intrusive images?"	Likert scale (single response) "Not at all vivid/compelling"; "Slightly"; "Moderately"; "Very"; "Extremely vivid/compelling"
	13	NSSI Imagery – Perceived impact on urge	Q8.3 "The intrusive images..."	Multiple choice (multiple responses) "Made me want to hurt myself more" "Made me want to hurt myself less" "No influence"
	14	NSSI Imagery – Perceived impact on behavior	Q8.4 "The intrusive images..."	Multiple choice (multiple responses) "Compelled me to act on my urge" "Compelled me to resist acting on my urge" "No influence"
	15	NSSI Imagery – Perceived impact on emotion	Q8.5 "Did you feel more positive (e.g., relief/release) or negative (e.g., guilt/shame) after experiencing the intrusive images?"	10-point VAS scale "0 Negative" – "10 Positive"
	16	NSSI Imagery – Temporal Focus	Q8.6 "Were you imagining..."	Multiple choice (multiple responses) "What happens before the self-injury act" "What happens during the self-injury act" "What happens after the self-injury act" "None of the above"
NSSI Verbal Thought	17	NSSI Thought – Frequency	Q9 "Since the last beep, did you experience negative self-talk related to self-harm"	Likert scale (single response) "Not at all"; "A little of the time"; "Some of the time"; "Most of the time"; "The whole time"
	IF Q17 response ≠ "Not at all"			
	18	NSSI Thought – Perceived impact on emotion	Q10 "Did you feel more positive (e.g., relief/release) or negative (e.g., guilt/shame) after experiencing the negative self-talk?"	10-point VAS scale: "0 Negative" – "10 Positive"

[a]Context questions were included as a buffer before NSSI-related questions and are not analyzed as a part of the study.

and (d) hypotheses 1 and 3. The EMA protocol, data, and analyses outputs (R markdown file) for cross-sectional analyses are available at: https://osf.io/gdyx2/?view_only=06a797b70f1d4493a89ed09090c54ef1. We report how we determined data exclusions and obtained scores for all measures in the study.

RESULTS

Participant characteristics

Out of the $N = 47$ participants invited to complete the EMA component of the study, four participants responded to less than 10% of scheduled EMA surveys and were excluded from further analysis. The final sample of $N = 43$ was 81% female (10% male, 7% non-binary/third gender, and 2% prefer not to say; mean age = 18.90, SD = 1.99, range = 17–24); mean education (years) = 13, SD = 1.12, range 11–18. In terms of race/ethnicity, 67% identified as Australian, 12% as Norther/Western European, 9% as South-East Asian, 5% as South-Central Asian, 5% as North-East Asian, and 2% as African.

Baseline psychological distress was high in the sample; 60% of the sample scored above 30 on the K10 (indicating high likelihood of having a mental disorder), median = 33, mean = 31.44, SD = 7.54, range = 13–48. Life-time suicide attempt was reported by 27.90% of participants. For suicidality within the past month, 46.50% of the sample reported suicidal desire, and 23.30% reported suicidal ideation. In terms of NSSI history, lifetime NSSI frequency for the sample ranged from 11 to 3778 times, median = 262 times, mean = 511.18 times, SD = 692.95. Age of NSSI onset ranged from 5 to 18 years of age, median = 13, mean = 13, and SD = 2.73. For NSSI methods, Cutting was reported by 67.40% of the sample, followed by Scratching (11.60%), Hitting (7%), Pinching (4.7%), Burning (2.3%), Biting (2.30%), Wound Interference (2.30%), and Hair Pulling (2.30%). As for the time between NSSI urge and acting on urge (behavior onset), (55.80%) participants reported the time window to be "less than 1 h", 32.6% reported "1–3 h", 4.70% reported "3–6 h", and 2.30% reporting "6–12 h." The majority of participants 74.40% reported wanting to stop NSSI, with 25.60% not wanting to stop.

EMA data summary

Across participants, a total of 3154 EMA survey responses were collected, of which 2944 (93.3%) were scheduled and 210 (6.70%) were self-triggered. Participants showed good compliance for scheduled survey completion, with a median completion rate of 75 of the 98 scheduled surveys (76.5%), with scheduled survey completion rate IQR = 57.00 to 82 (58.1% to 83.7%). Scheduled survey missingness was not related to age ($r = -0.19$), education ($r = -0.06$), or lifetime NSSI Frequency ($r = -0.04$), age of NSSI onset ($r = -0.11$), all $p > 0.05$. Gender was related to missingness, where females were more likely to complete surveys than males, $F(1, 37) = 4.996$, $p = 0.032$. See Appendix E in Appendix S1 for a summary of NSSI behavior functions reported during the EMA period.

NSSI function

Across the 14-day study period, NSSI was reported on 102 occasions by 31 (72.1%) participants, above the minimum of 100 target events required. The frequency of NSSI reported by the 31 participants ranged from 1 to 15, with a median of 1. On the 102 occasions when NSSI behavior reported, the function of "to release tension/to relax" was reported on 63 occasions (61.8%), "to stop/gain relief from bad feelings" was reported on 52 occasions (51%), "to punish myself" was reported on 27 occasions (26.5%), "To feel in control" was reported on 22 occasions (21.6%), "to feel something/stop feeling numb" 13 occasions (12.7%) of the time, "to get other people to act differently/change" on 3 occasions (2.9%) of the time, and "to stop suicidal thoughts & feelings" on 1 occasion.

NSSI cognition

During the EMA period, 3120 surveys had valid ratings for NSSI Imagery, and 3115 had ratings for NSSI Verbal Thought. Of these, NSSI Imagery was reported as having occurred since the previous survey on 456 (14.62%) occasions, and NSSI Verbal Thought was reported as having occurred since the previous survey on 493 (15.83%) occasions.

Participants' mean frequency of EMA NSSI Imagery[2] was positively related to Total lifetime NSSI frequency, $r = 0.660$, $p < 0.001$, but not related to Age of NSSI onset, $r = -0.271$, $p = 0.522$. Mean EMA NSSI Imagery frequency was also positively related to baseline imagery generation tendency (SUIS score, $r = 0.444$, $p = 0.029$), but not baseline imagery generation ability (vividness; VVIQ score, $r = 0.323$, $p = 0.275$). In contrast, mean EMA NSSI Verbal Thought frequency was not related to Total lifetime NSSI Frequency, Age of NSSI onset, or baseline imagery tendency (SUIS) or ability (VVIQ), all $r \leq |0.218|$, all $p \geq 0.999$.

H1: NSSI imagery tracks dynamically with urge

A general mixed-effects model was fitted with NSSI Cognition Frequency and Cognition Format (Imagery vs. Verbal Thought) as interactive fixed effect predictors of Urge, with Subject fitted as random intercept and Cognition Format as random slope. Consistent with predictions, results revealed a main effect of Cognition Frequency, where higher frequency was associated with higher NSSI Urge. This main effect was further qualified by a significant two-way interaction with cognition format. As shown in Table A in Appendix S1, fixed effects from the full model involving the interaction term accounted for 31.1% of variance in

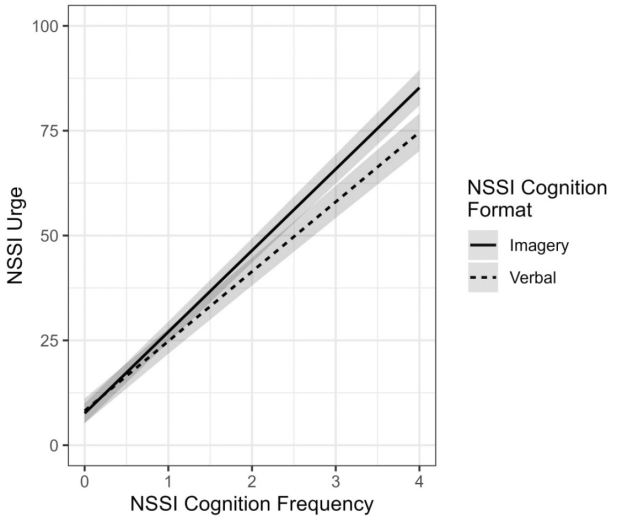

FIGURE 1 Predicted values of NSSI Urge as a function of Cognition Frequency and Format (Mental Imagery vs. Verbal Thought). Cognition Frequency was rated from "0 – not at all" to "4 – The whole time."

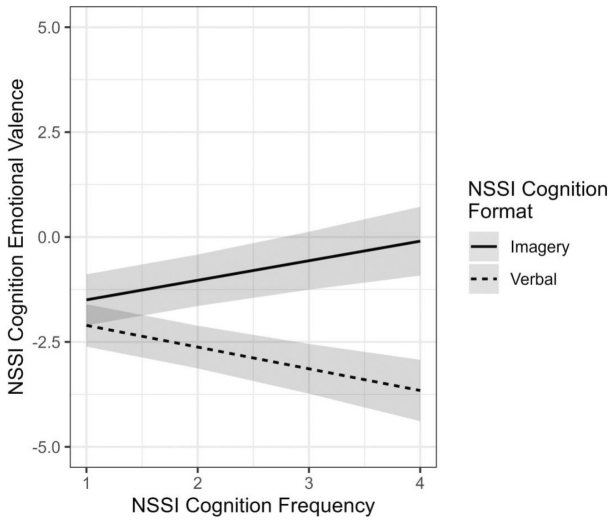

FIGURE 2 Predicted values of NSSI Cognition Emotional Valence as a function of NSSI Cognition Frequency and NSSI Cognition Format (where Cognition Frequency was rated as "1 – A little of the time"; "2 – Some of the time"; "3 – Most of the time"; and "4 – The whole time").

urge, although the interaction effect itself was very small, accounted for 0.4% additional variance ($R^2\Delta = 0.004$). As depicted in Figure 1, the positive relationship between cognition frequency and urge was slightly stronger for Imagery than for verbal thoughts.

H2: NSSI imagery content

Consistent with predictions, out of 454 valid reports of imagery, the majority (378, 83.48%) involved depictions of "what happens *during* the self-injury act", and 174 (38.33%) depicted "what happens *after* the self-injury act", 64 (14.10%) depicted "what happens *before* the self-injury act" (before NSSI), and 16 (3.52%) had no temporal focus (atemporal). In terms of content focus, out of 455 valid reports, two-thirds (305; 67.03%) were related to "*How I would carry out the act of hurting myself*"; 241 (52.97%) were related to "*The release/relief" of hurting myself*, 83 (18.24%) were related to "*The downsides of hurting myself*", and 72 (15.82%) involved "*Other*" content. 85.49% of imagery was related to either actions or benefits, and 34.51% was related to both.

The emotional valence of NSSI imagery versus verbal thought

Exploratory analyses were conducted to examine of the Emotional Valence of NSSI Imagery and Verbal Thought as a function of Cognition Frequency. As reported in more detail in Appendix F in Appendix S1, a general mixed-effects model was fitted with NSSI Cognition Frequency and NSSI Cognition Format (Mental Imagery vs. Verbal Thought) as interactive fixed effect predictors of NSSI Urge, with subject fitted as random intercept and Cognition Format as random slope. As shown in Table B in Appendix S1, no main effects were found, but a two-way interaction between NSSI Cognition Frequency and Cognition Format was found, accounting for half of the variance explained by the full model ($R^2_{(\text{full model})} = 0.084$; $R^2\Delta = 0.040$). As depicted in Figure 2, the emotional valence of NSSI Verbal Thought becomes more negative at higher frequencies, while NSSI imagery becomes less negative at higher frequencies.

H3. NSSI imagery as a driver of NSSI urge

Perceived impact on urge

More than half (59.30%) of NSSI Imagery was perceived as having "Made me want to harm myself more" (Increased Urge), 26.87% were perceived as having "No influence", and 14.10% as "Made me want to harm myself less" (Decreased Urge).

Cross-panel analysis

A cross-lagged panel analysis model was conducted to examine the temporal relationship between NSSI Imagery Frequency, Imagery Vividness, and Urge across time. As

TABLE 2 Cross-lagged panel model predicting NSSI Urge at T + 1 with NSSI Urge at T and Imagery variables between T and T + 1.

Variables predicting NSSI urge (T + 1)	Standardized Coefficients	SD	95% C.I.
NSSI Urge (T)	**0.217***	**0.031**	**0.154, 0.275**
Imagery Frequency (T to T + 1)	**0.203***	**0.028**	**0.149, 0.258**
Imagery Vividness (T to T + 1)	0.012	0.063	0.107, 0.141
Imagery Frequency (T to T + 1) × Imagery Vividness (T to T + 1)	−0.048	0.066	−0.181, 0.076
R-squared	0.10 (0.08–0.13)		

Note: Coefficients are standardized coefficients, with 95% credibility intervals.

* indicates the estimate is significantly different from zero.

TABLE 3 Cross-lagged panel model predicting the likelihood of NSSI Behavior at T + 1 with NSSI Urge at T and Imagery variables between T and T + 1.

Variables predicting NSSI behavior (T + 1)	Standardized Coefficients	SD	95% C.I.
NSSI Urge (T)	**0.201***	**0.067**	**0.059, 0.326**
Imagery Frequency (T to T + 1)	**0.361***	**0.092**	**0.163, 0.525**
Imagery Vividness (T to T + 1)	0.007	0.194	−0.374, 0.428
Imagery Frequency (T to T + 1) × Imagery Vividness (T to T + 1)	−0.279	0.208	−0.607, 0.170
R-squared	0.25 (0.09–0.41)		

Note: Coefficients are standardized coefficients, with 95% credibility intervals.

* indicates the estimate is significantly different from zero.

shown in Table 2, the model accounted for 10% of variance in Urge across time. As expected, higher Urge at T predicted higher Urge at T + 1. Consistent with H3a, greater Imagery Frequency (between T and T + 1) predicted higher Urge at T + 1, over and above Urge at T. Imagery vividness did not independently predict Urge at T + 1 and did not moderate the relationship between Imagery Frequency and NSSI Urge across time. As such, consistent with the hypothesis that NSSI Imagery drives NSSI Urge, results show that greater occurrence of NSSI Imagery predicts greater NSSI Urge at the next time point, over and above the effect of NSSI Urge at the previous timepoint.

Moderation by NSSI imagery content

Perceived impact of NSSI imagery on Urge is presented in Table C in Appendix S1 (Appendix G in Appendix S1). Exploratory cross-panel analyses of imagery content category as moderators of the cross-temporal relationship between NSSI Imagery frequency and Urge are also reported in Appendix G and Table D in Appendix S1.

Exploratory: NSSI Imagery as a driver of NSSI behavior

Perceived impact on behavior

Less than half (43.70%) of NSSI imagery was perceived as having "Made me want to harm myself more" (Increased Likelihood of Acting on Urge), 36.20% were perceived as having "No influence", and 20.09% as "Made me want to harm myself less" (Decreased Likelihood of Acting on Urge).

Cross-panel analysis

A cross-lagged panel analysis model was conducted to examine the temporal relationship between NSSI Imagery Frequency, Imagery Vividness, and NSSI Behavior across time while controlling for Urge. As shown in Table 3, higher Urge at T predicted greater likelihood of NSSI behavior at T + 1. In addition, greater Imagery Frequency (occurring between T and T + 1) also predicted greater likelihood of NSSI Behavior at T + 1, over and above the effects of NSSI Urge at T. The Vividness of Imagery did not independently predict Urge at T + 1 and did not moderate the relationship between Imagery Frequency and NSSI Urge across time. Results show that greater occurrence of NSSI Imagery predicts greater likelihood of NSSI Behavior at the next time point, over and above the effect of NSSI Urge at the previous timepoint.

Moderation by NSSI imagery content

Perceived impact of NSSI imagery on NSSI behavior is presented in Appendix H in Appendix S1. Exploratory cross-panel analyses of imagery content category as moderators of the cross-temporal relationship between NSSI Imagery frequency and Behavior could not be performed due to low instances of NSSI imagery in each content category for NSSI behaviors occurred.

DISCUSSION

Using a 14-day intensive EMA protocol, this study investigated the role of NSSI-related mental imagery as a dynamic and proximal driver of NSSI urge and behavior in a community sample of young people aged 17–24 with a history of NSSI. Results provide the first real-time evidence that fluctuations in NSSI urge are accompanied by mental imagery of NSSI, and high urge was accompanied by mental preoccupation in the form of NSSI imagery as well as verbal ideation. NSSI imagery predominantly depicted "flash-forwards" to the actions, bodily sensations, and emotional benefits involved in carrying out NSSI. In terms of perceived impact, almost 60% of images were appraised as having increased urge (vs. only 14% as having decreased urge), and 44% as having increased the likelihood of acting on urge (vs. 20% having decreased the likelihood of acting on urge). Critically, objective cross-panel analyses were consistent with participants' perceptions, as higher NSSI imagery frequency predicted greater subsequent increases in NSSI urge over and above the effects of existing urge. The same pattern was found for behavior, where higher NSSI imagery frequency predicted greater subsequent likelihood of NSSI behavior over and above the effects of existing urge.

Theoretical implications

The present findings are consistent with the hypothesis that imagining oneself engaging in NSSI is not simply an epiphenomenal by-product of experiencing NSSI urge but rather functionally contributes to the intensification of NSSI urge and the likelihood of urge being acted upon. Given that participants were surveyed every 30 min to 2.5 h, the findings indicate that NSSI-related mental imagery may constitute a proximal and dynamic driver of NSSI urge and behavior.

Further, the exploratory finding that NSSI imagery also predicts future likelihood of acting on urge, over and above the effects of existing urge, suggests that mental imagery may drive NSSI both indirectly via its impact on urge as well as its directly via its impact on behavior. Although preliminary, the present findings considered in the context of known basic properties of mental imagery and its functional impact on other behavioral domains, it is possible that mental imagery may contribute to NSSI via two routes: (a) an indirect route via its motivational impact on urge; and (b) a direct route via its facilitation of action planning and execution. Influential theories of suicidal self-injury, such as the Integrated Motivational–Volitional (IMV) model (O'Connor & Kirtley, 2018), already implicates mental imagery at the volitional phase due to its action rehearsal properties. Mental imagery may thus serve similar action-facilitating functions in NSSI. At the same time, the motivational impact of imagining self-injury as a form of reward anticipation warrants greater attention in suicidal self-injury, as noted in earlier research (Crane et al., 2012; Hales et al., 2011; Holmes et al., 2007; Ng et al., 2016).

Potential clinical implications

The present findings indicate that flash-forward mental imagery of NSSI constitutes a neglected risk assessment and intervention target. The present study showed congruence between participants' perceived functions (impact on urge and behavior) and objective analyses of impact via cross-panel analysis of relationships across time. Routine assessment of the frequency, content, perceived functions, and impact of NSSI imagery in clinical settings may provide important insights on dynamic fluctuations of NSSI risk and motivators of NSSI that may otherwise be missed. As such, the development of an NSSI imagery screening instrument is needed to facilitate research in this area. In addition, the incorporation of psychoeducation concerning the nature and functional impact of imagining NSSI may facilitate clinical formulation and treatment.

This study provides evidence in support of the need to develop novel interventions specifically designed to target mental imagery in NSSI. Researchers have already been developing brief and scalable NSSI-specific psychological interventions designed to promote mental imagery of alternative coping behaviors (May, Andrade, & Kavanagh, 2015). For example, Di Simplicio and colleagues developed a transdiagnostic mobile app-delivered intervention that adapted Functional Imagery Training (Andrade et al., 2012; Kavanagh et al., 2014) to motivate engagement in alternative coping strategies through guided imagery designed to increase the reward salience of proximal incentives of working towards their goals (of not engaging in NSSI) (Di Simplicio et al., 2020). The preliminary randomized controlled trial of the Imaginator app indicated safety and feasibility and provided initial indications of greater efficacy in reducing NSSI behavior relative to usual care within a stepped wedge design (Di Simplicio et al., 2020). Mental imagery can, of course, also be used to increase the salience of proximal costs of NSSI, although exploratory results from this study provided no evidence to support the idea that increasing attention to the costs of NSSI serves to dampen NSSI urge.

In yielding preliminary evidence that mental imagery of NSSI functionally contributes to NSSI urge and behavior, results from the present research indicate that in addition to leveraging mental imagery to promote alternative

coping behaviors, it may be important to directly target NSSI imagery with the aim of reducing its motivational impact. Novel forms of working with mental imagery from a cognitive-behavioral therapy perspective would be worthwhile (Hackmann et al., 2011; Holmes et al., 2019). Another approach may be to harness imagery-competing task interventions to dampen the emotional and motivational impact of mental imagery, such as via visuospatial computer games (Iyadurai et al., 2023) or eye movements (Van Bentum et al., 2017, 2024). Finally, there is growing recognition that imagery rescripting may be a useful technique for flash-forward suicidal imagery (Paulik et al., 2024), and its role in NSSI should also be investigated.

Limitations and future directions

First, it should be acknowledged that the present findings reflect preliminary results from a restricted and close-ended set of hypothesis-driven questions about NSSI mental imagery. The study was conducted with a relatively small sample of late adolescents and young adults. Thus, the extent to which the present findings generalize to children and younger adolescents remains to be established. Prior cohort studies have shown that NSSI behavior increases during early adolescence and significantly declines after 25 years of age (Daukantaitė et al., 2021; Moran et al., 2012), likely reflecting life-stage, hormonal, and brain maturation-related changes in general distress and emotion regulation, but the strength of the relationship between general distress and NSSI itself does not appear to differ as a function of age (or gender) (Wilkinson et al., 2022). Thus, it is possible that the strength of the association between NSSI imagery and NSSI urge and behavior would be similar across age, but the prevalence of NSSI imagery may fluctuate as a function of development-related changes in NSSI itself. Alternatively, it is also possible that the strength of the relationship between NSSI imagery and NSSI urge and behavior would weaken with age as a result of developmental increases in executive function and self-regulatory control.

Relatedly, the study was conducted in a low suicide-risk sample (no attempts in the past 24 months and no current active planning of suicide) due to requirements from the Ethics Committee. As such, the extent to which the present results generalize to samples with higher suicide risk remains to be investigated in future research. Given the links between NSSI and suicidality, it will be important for future research to delineate the similarities and differences between mental imagery relating to NSSI versus SSI. While mental imagery may serve to motivate NSSI as well as SSI (May, Andrade, & Kavanagh, 2015), there may be qualitative or quantitative differences between the content and function of NSSI and SSI imagery. It will also be important to investigate whether the strength of association between NSSI imagery and NSSI urge and behavior differs as a function of suicide risk level within and across individuals.

Future research should also investigate NSSI mental imagery as a function of individual differences, such as NSSI onset age. While the present study did not find evidence of a cross-sectional association between NSSI imagery frequency during the EMA period and age of NSSI onset (which ranged from 5 to 18 years of age in the present sample), it would be important for future research to examine the relationship between NSSI imagery and NSSI behavior fluctuation in those with early onset versus late onset age, as it is possible that neurocognitive alterations in pain and reward processing due to early NSSI onset (Cummings et al., 2021) may result in onset age-related variations in within-person differences in the relationship between NSSI imagery and NSSI urge and behavior.

An additional limitation of this study is that, due to participant burden factors, many aspects of NSSI cognition were not able to be explored. First, this study did not assess the intrusiveness and controllability of NSSI imagery; thus, the extent to which NSSI imagery is experienced as unwanted intrusions is unclear. Future research should investigate these features for a comprehensive understanding of the nature of NSSI mental imagery, including the intrusive NSSI images in the context of other negative intrusive thinking known to be elevated in individuals with NSSI history (Batey et al., 2010). Second, the study's limited focus on verbal NSSI cognition constrains the study's capacity to compare imagery versus verbal NSSI cognition. Investigating possible content and functional differences between imagery and verbal-based NSSI mental preoccupation is an important area of future research, as they tend to co-occur, example, "*Self-harm is always sitting in your mind, and if I am watching the telly or something, I'll be thinking about it, and it will be like, 'Oh, I need to self-harm, I didn't self-harm earlier; I have to self-harm later.' Then I build all these plans in my head for when I am going to self-harm, what I'm gonna use, what I'm gonna do after I self-harm, how I'm gonna deal with it*" (Miller et al., 2021). While the present study found that the quantity of both imagery and verbal thinking about NSSI strongly tracks with urge (Figure 1), the emotional valence of NSSI imagery diverges from NSSI verbal thoughts at higher frequencies (Figure 2), suggesting there may be qualitative distinctions in the content and/or function of imagery versus verbal thoughts about NSSI. Specifically, results indicated that verbal-based mental preoccupation was more emotionally negative than imagery; thus, it is possible that, similar to craving imagery in other behavioral domains, individuals engage in negative self-talk in an attempt to suppress urge

when urge is high, while at the same time experiencing mental imagery depictions of desired targets (Månsson et al., 2023).

Another study limitation stemming from the need to reduce participant burden is that the present study only asked participants to rate the direction of perceived functional impact of NSSI imagery (i.e., increased, decreased, or no impact). While this categorical approach enabled this study to conduct initial quantification of perceived functional impact, future research should extend the present design beyond direction of impact to assess magnitude of impact in either direction via a continuous scale, such as a bi-modal 9-point Likert scale with no impact in the middle.

Further, while the present study had a particular theoretical and methodological focus on the indirect relationship between NSSI imagery and behavior via its motivational impact on NSSI urge, future research should extend this research to further investigate the mechanisms underlying direct influences of NSSI imagery on behavior, such as via facilitating behavioral rehearsal and action planning (as proposed by the Integrated Motivational-Volitional Model of Suicidal Self-Injury; O'Connor & Kirtley, 2018).

CONCLUSION

Mental imagery of NSSI constitutes a novel cognitive mechanism underpinning NSSI. Mental pre-occupation with NSSI in the form of imagining the actions, bodily sensations, and emotional consequences appears to be functionally contributing to urge intensification and increasing the likelihood of acting on urge, rather than being a mere by-product of high urge. Future research should further elucidate the nature of NSSI-related mental imagery and further establish its causal impact on NSSI urge and behavior.

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CONFLICT OF INTEREST STATEMENT

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SUPPLEMENTAL MATERIAL

https://osf.io/gdyx2/?view_only=06a797b70f1d4493a89ed09090c54ef1.

ORCID

Julie L. Ji https://orcid.org/0000-0003-1688-9708

ENDNOTES

[1] As shown in Supplementary Materials, based on McEvoy et al.'s (2017) retrospective self-report findings that NSSI imagery content focusing on actions and emotional benefits was perceived to increase the likelihood of acting on urge, whereas imagery focused on the costs of NSSI decreased the likelihood of acting on urge, we also explored whether the impact of NSSI imagery on NSSI urge and behavior differed as a function of imagery content at subjective and objective cross-temporal levels.

[2] When NSSI Imagery was reported as having occurred since the last survey, the average frequency with which it occurred (1 – A little of the time to 4 – The whole time).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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