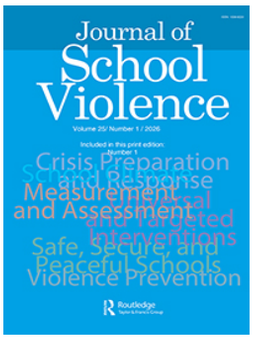

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Perceived Proximal Warning Behaviors in Cases of Severe Targeted Violence at German Schools: A Retrospective Longitudinal Analysis

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ABSTRACT

The recognition and management of students who exhibit warning behaviors (WBs) is an important prerequisite for the prevention of severe targeted acts of violence at schools (STSV). In the present study, the temporal occurrence of proximal WBs was retroactively examined in 11 German cases. The WBs were plotted chronologically, starting from the initial WB up to the day of the STSV. Only the behavior perceived at the time was evaluated, without including information that only became known after the STSV. A prototypical temporal order of initial perception was identified. In each case, WBs were already perceived before the first Leakage or Directly communicated threat. WBs can usually only be recognized as such in a wider psychosocial context (e.g. including information about current psycho-social crises). The findings highlight the need to establish structures at schools in cooperation with other institutions as part of a threat assessment and management for indicated prevention.

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Severe targeted school violence; school shooting; threat assessment; proximal warning behaviors; leakage; retrospective longitudinal study; youth violence

Severe targeted violence at schools (STSV) refers to cases "committed by former or current students intending to kill one or more persons associated with their school." (Sommer et al., 2020, p. 1). It is a worldwide phenomenon that is receiving increased public attention (e.g., Leuschner et al., 2017). In the US, more offenses were reported between 2000 and 2018 than in the rest of the entire twentieth century (Katsiyannis et al., 2018), with 675 such offenses recorded between 2020 and 2022 (Riedman, 2023). Two of the deadliest cases worldwide occurred in Germany: the 2002 STSV at Gutenberg Gymnasium in Erfurt with 17 fatalities and the 2009 STSV at Albertville Realschule in Winnenden with 16 fatalities. Although the probability of experiencing such an offense personally is very low (e.g., Peterson et al., 2023), the consequences go far beyond the pure number of victims and are complex for politics, schools, and society. These events strongly influence, for example, the sense of security and cause traumatization and great uncertainty for witnesses, their families, and communities (cf., Ahlig et al., 2016; Silva et al., 2023).

Threats of STSV at school

In contrast to committed violent acts, threats of STSV are frequent. They often lead to evacuations, police searches, criminal investigations and lost teaching time (Peterson et al., 2023). In Texas (US), for example, four threats per school were recorded across 16,845 schools between 2021 and 2022 (Peterson et al., 2023). In Berlin (Germany), an average of 0.02 threats per school was registered by the police in 2019, which corresponds to approximately one threat every three weeks across all Berlin

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schools (Police query, LKA Berlin, 18.10.2023). However, as not all threats are reported to the police (Peterson et al., 2023), the true extent of such threats remains unknown. Schools and police officers are faced with the problem of reacting appropriately and choosing interventions proportionately. Research findings that help to accurately assess threats of STSV in terms of their degree of dangerousness are critically important.

Current state of research

STSV is the final result of a longer pathway to intended violence taken by the later perpetrator. Behavior of concern and signs of personal crises can be observed during the perpetrator`s pathway to intended violence (e.g., Leuschner et al., 2017). This conscious or unconscious behavior, which can be observed by other persons, is often referred to as "leaking," "leakage," or "warning behavior." This can be announcements of intention to carry out an act of violence to friends, making direct death threats to the alleged victims, or behaviors that indicate psychosocial crisis experiences, such as suicidal ideation following a breakup with a partner (Fiedler et al., 2020). Such statements could be the result of the later perpetrator being so preoccupied with the subject that he or she finds it difficult to keep his or her thoughts completely to himself or herself (Meloy, Hoffmann, et al., 2021). Studies consistently show that in the majority of cases, the perpetrator engaged in such behavior prior to their act of violence. For example, the National Threat Assessment Center (2021) confirmed in a sample of prevented STSVs that 94% of those students communicated information about their planned offense to others. The authors also showed that 67% of the sample had an interest in other violent acts, including school shootings, serial or mass murderers, terrorism, and 100% showed planning behavior. American and German studies indicate that, for most perpetrators, at least one person had knowledge of the intentions of the perpetrator prior to their act of violence ("bystander"; e.g., Fiedler et al., 2020). This knowledge is often not shared with teachers or parents ("code of silence"; Fein et al., 2002), as the bystanders usually did not take the information seriously (Fiedler et al., 2020). Adults are therefore often unaware of the expressed intentions. A German study revealed that, in all 11 investigated cases, the behavior of the perpetrator in the path to their act of violence was noticed by at least one school authority; however, it was usually trivialized and in only two out of the 11 cases, appropriate responses were made (Fiedler et al., 2020). It is noteworthy that, in the German educational system, there is neither a statutory obligation for documentation nor a mandatory internal reporting obligation. Consequently, essential information regarding students is not exchanged internally in schools. This phenomenon is referred to in the literature as "institutional memory loss" (Fox & Harding, 2005, p. 75).

In summary, it can be said that perceptible information about the problematic inner life of later perpetrators is to be seen as a great – and perhaps the only – chance to recognize a potential negative developmental path and to prevent a later act of violence.

The concept of warning behaviors

The concept of WBs was introduced as "a useful means of conceptualizing behavioral patterns indicating increasing threat (Meloy et al., 2012, p. 260; Meloy, Hoffmann, et al., 2021, p. 1)." The eight proximal factors describe "behavioral or psychological patterns that constitute change and may evidence accelerating risk (Meloy, Hoffmann, et al., 2021, p. 1)." They include: (1) *Pathway* - research, planning, or implementation, (2) *Fixation* - abnormal preoccupation on an individual or cause, (3) *Identification* - self-identification as a fighter/warrior/agent of change, (4) *Novel aggression* - an initial violent action which is unrelated to the target, (5) *Energy burst* - an increase in the frequency or variety of behaviors which are related to the targeted individual or cause leading up to a violent incident, (6) *Leakage* - communication to an outside party of the individual's intent for violence which can be unconscious or conscious, (7) *Last resort* - the person feels that there is no other way to solve the grievance other than violence, and for that violence to be now they feel

violence is their only option, and (8) *Directly communicated threat* - communication of violence to target or law enforcement before action (Meloy, Hoffmann, et al., 2021). The Terrorist Radicalization Assessment Protocol (TRAP-18; Meloy, 2017) is a collection of 18 behavior-based warning signs for terror incidents (see Allely & Wicks, 2022). The TRAP-18 consists of the eight proximal characteristics and ten additional distal characteristics: *personal grievance and moral outrage; framed by an ideology; failure to affiliate with an extremist group; dependence on virtual community; thwarting of occupational goals; changes in thinking and emotions; failure of sexual-intimate pair-bonding; mental disorder, greater creativity and innovation* and *criminal violence* (Meloy, Goodwill, et al., 2021). As the proximal WBs listed here are more closely linked to the act of violence and information about them is more fact-based and observable, such as an explicit death list, the present study focuses on the proximal WBs. In the following, the term *WBs* is used to refer to proximal WBs.

As part of a threat assessment, the overall circumstances of a student are evaluated, e.g., behavior, school performance, family circumstances, and situation in the classroom. The assessment determines whether the student has expressed any WB and whether their behavior or *Directly communicated threat* or *Leakage* constitutes a substantial threat (Cornell & Maeng, 2024). Meloy et al. (2014) compared perpetrators of STSV with students showing "some form of threatening or worrying communication" (p. 14), but without the intention of committing an act of violence, in terms of existing WBs ($N = 31$). The group of perpetrators showed five WBs significantly more often than students from the comparison group: *Pathway, Fixation, Identification, Novel aggression*, and *Last resort*.

To date, only one longitudinal study on the WBs has been conducted. Meloy, Goodwill, et al. (2021) obtained a sample of 125 lone-actor terrorists who had "purported" ideologies ranging from Extreme Right Wing (XRW) to Islamic Jihadist terrorism and analyzed the sequences of behaviors organized over time. Their findings indicate that *Pathway*, *Leakage*, and in some cases, *Directly communicated threat*, may be critical points for intervention.

A large part of the empirical validation of the WBs was done using terrorism samples (e.g., Meloy, Goodwill, et al., 2021). There are very few studies to date on WBs in cases of STSV (e.g., Abel et al., 2022; Erlandsson & Meloy, 2018). Although there are similarities between cases of terroristic violent acts and STSV (Böckler et al., 2018), findings from studies on terroristic cases cannot be transferred easily to cases of STSV, as, for example, the school context is unique and perpetrators of STSV are usually younger than perpetrators of terroristic acts. However, research has shown that both groups share developmental processes and social mechanisms, such as social isolation, accumulated grievances, and fixation on a biased – that is "hostile" – perception of reality (see Allely et al., 2024). These similarities have led to an increasing discussion on the role of radicalization in STSV cases and the need for further empirical validation (Böckler et al., 2018). While Allely et al. (2024) demonstrated that the WBs can be successfully applied to STSV cases, further studies are needed to expand empirical validation of the WBs in this context.

Current study

In studies examining WBs, the total amount of WBs is usually considered, including information that only became known *after* the actual act of violence (information that only the *perpetrator* could have known before the act of violence, e.g., information from diaries). However, information that is not known before an event cannot be used to make predictions. Studies often make the temporal mistake of drawing conclusions from data that only became known after an act of violence. They then use this information to make a prediction for the time before the STSV.

For a threat assessment using the WBs, it is necessary to have information about the typical temporal order of WBs on the pathway to intended violence. However, previous studies on WBs have only been conducted using cross-sectional analyses. There is still a lack of studies investigating the chronological occurrence of WBs longitudinally. The present study aims to address this

gap – it is the first study to investigate WBs in selected cases of STSV in a retrospective longitudinal study. The WBs were plotted chronologically. We aimed to identify a prototypical temporal order of the initial perception of the WBs. The following research questions were investigated:

(1) In the pathway to intended violence of the perpetrators of STSVs, when are the WBs initially noticed by other persons?
(2) How often are the WBs observed?
(3) Are certain WBs perceived more frequently close to the STSV?

Methods

Data and material

The current study includes nonpublic court records and investigation files of 11 German cases of STSV, committed between 1999 and 2013. These constitute the complete population of documented cases in Germany up to 2013. Cases were included if they met the following inclusion criteria: (1) violent act was planned and executed by a current or former student of a school; (2) potentially lethal weapons were used (including non-shooting weapons, such as bombs or large knives); (3) the intent to kill at least one person associated with the school; and (4) the perpetrator was not older than 25 years when they committed the act of violence (cf. Bondü & Scheithauer, 2014). Using media databases, newspapers were systematically screened for the terms "Amok (rampage)," "School Shooting," "Terroranschlag (terrorist attack)," and "Mordanschlag (assassination attempt)." This search yielded 46 cases of potentially lethal school violence. Of these, 11 cases met our inclusion criteria. The sampling strategy is described in detail in Fiedler et al. (2020). The resulting sample comprises nine male and two female perpetrators. The age varies between 13 and 23 years ($M = 17.5$, $SD = 2.8$). Five of the perpetrators committed suicide after perpetrating the STSV.

Coding and coding instrument

In the present study, we refer to the conceptualization of the WBs by Meloy et al. (2012). Data from the case files were coded with the help of the interdisciplinary analysis tool TARGET Threat Analysis Instrument (TTAI, Ahlig et al., 2020), which was developed and validated on STSV threat case records. These nonpublic case records include only legal documents by police and court and consist of, e.g., police reports, interrogations of the perpetrator, and witnesses and forensic investigations.

The TTAI is used to systematically code characteristics of STSV threats. It consists of several sections, such as "legal consequences," "content of threat," and "authority's reaction." The "warning behavior" section contains 13 items that code individual aspects of the WBs (e.g., for *Identification*: dealt intensively and repeatedly with real or fictional perpetrators of violence, viewing/revering them positively and identifying with them). Two additional items measure *Leakage* and *Directly communicated threats*. Each item was measured as being either "behavior is present," "is not present," or "cannot be assessed on the basis of information from the file." In addition, according to Meloy et al. (2012), *Energy burst* was coded as an increase in activity and energy. Moreover, we coded states of tension that are not directly related to the act of violence but still reflected heightened arousal. This coding is based on the concept of clandestine excitement (Collins, 2012). *Novel aggression* was coded as physical violence against living beings and objects, committed for the first time. For example, a perpetrator physically assaults a classmate for the first time. All specific behaviors that could be depicted with the help of these items from the files were coded. The behavioral patterns were plotted chronologically. This resulted in a temporal occurrence for each case, starting from the initial WB up to the day of the STSV. Figure 1 shows the temporal occurrence of the 11 cases.

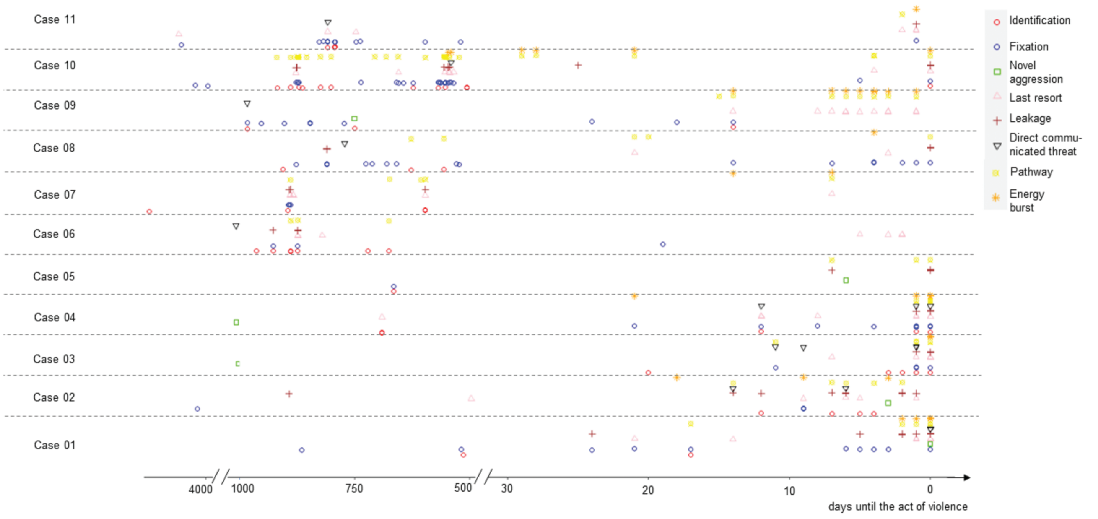

Figure 1. Temporal occurrence of WBs across all cases ($N = 11$).

Coding rules

Only the behavior present at the time was evaluated – without including information that only became known retrospectively, after the STSV had already been committed.

Perception of WBs

A distinction was made between a) potentially perceptible behavior by other persons that was documented/reported exclusively by the perpetrator and not mentioned by any witnesses and b) actually perceived behavior that was reported by witnesses or the perpetrator reported an interaction between the perpetrator and witnesses. To reduce bias, we only included actual perceived behavior.

Threat assessment perspective

For the purposes of the present study, it is irrelevant whether the perceiving person assessed the behavior of concern as conspicuous at the time of perception. A death threat, for example, which was interpreted as a joke by the perceiver, is evaluated as a *Directly communicated threat* or *Leakage* from the perspective of the threat assessment.

Point in time at which the WBs were perceived

The relevant time is always the time at which another person actually becomes aware of a WB. If a person only becomes aware of a WB at a later point in time, e.g., through the perpetrator's report, it is not the original time of the behavior that is coded, but the time of the perpetrator's report. If it was only possible to identify a period of time for the respective behavior, the midpoint was coded. If no time period could be identified, the behavior was not included ($M = 5$, $SD = 3$, $min = 0$, $max = 11$). If WBs occurred repeatedly within an event in a short period of time (e.g., within a single hour), it was coded only once.

Perceived non-behavior

Perceived non-behavior was also coded as WB if, in the opinion of the raters, it contains aspects of WBs, such as defensive behavior and non-reaction to attacks as a *Fixation* regarding perceived injustice.

Quality criteria

Two of the authors completed the coding independently (Cohen's Kappa = .89, 1,141 behaviors). In cases of disagreement, we discussed the issue until we reached a consensus (consensus coding).

Analyses

The data points were recorded into the number of days remaining until the act of violence. A time series was obtained for each case showing the temporal occurrence of the WBs (Bortz & Lienert, 1998). The values were z-transformed within each case to ensure a uniform distribution. This allowed the temporal occurrence to be compared between cases. The study compared all parameters between the cases (research question 1: number of days remaining until the act of violence, research questions 2 and 3: frequency of WBs). To compare time periods for the third research question, we categorized the temporal occurrence into six-month time phases. Due to the small sample size – five of the 11 cases contain fewer than 50 observations (see Holden et al., 1990) – the research questions were examined using frequency distributions or distribution-free analyses. A significance level of 10% was accepted (Bortz & Lienert, 1998). The SPSS 28 program was used for the statistical analyses.

Results

In Table 1 the descriptive characteristics of the cases are presented. The length of a temporal occurrence varies from 5 to 15.64 years. The age at which the first WB was perceived varied between 4.64 and 14.29 years old.

Table 1 also shows that in all cases another WB was already perceived by any person before the first *Leakage* and the first *Directly communicated threat*. The first *Leakage* occurred 70 to 2,080 days before the act of violence (2.3 months to 5.7 years before the act of violence), the first *Directly communicated threat* 0 to 2,164 days before the act of violence (on the day of the offense to 5.93 years before the act of violence). In all but three cases (cases 6, 7, 9) the last *Leakage* or *Directly communicated threat* was made on the day of the act of violence or one day before. The highest total number of WBs was observed in cases 8 and 10 (95% CI = 131.42). Examples for each WB can be found in the Appendix.

The initial occurrence of the type of WBs (e.g., the first *Pathway*) was explored and presented in Table 2 (e.g., the initial occurrence of *Pathway* is on average of 760 days before the act of violence, *MD* = 360 days). A Kruskal–Wallis test for independent samples revealed significant differences between the initial occurrence of the types of WBs ($H = 46.85$, $df = 7$, $p \leq .001$). Pairwise comparisons were

Table 1. Descriptive characteristics of the cases ($N = 11$).

Case	Length in days[a]	Length in years[b]	Initial WB	Age at initial WB in years	Initial Leakage in days[c]	Initial Dcr in days[d] (n = 10)	Last Leakage in days[e]	Last Dcr in days[f] (n = 10)	Last Leakage/ Dcr in days[g]	WBs total[h]
1	1826	5.00	Identification	11.15	138	0	0	0	0	69
2	4256	11.66	Fixation	4.64	892	110	1	6	1	102
3	1847	5.06	Novel aggression	11.48	222	1226	0	1	0	88
4	2516	6.89	Novel aggression	8.01	105	12	0	0	0	71
5	2571	7.04	Fixation	6.79	70	55	0	55	0	51
6	3005	8.23	Fixation	14.29	2080	2164	873	2164	873	87
7	5710	15.64	Identification	7.62	892	–	282	–	282	50
8	2490	6.82	Identification	12.45	810	771	0	96	0	176
9	3174	8.70	Identification	8.94	330	983	321	55	55	126
10	4318	11.83	Fixation	6.74	1902	540	0	80	0	191
11	4825	13.22	Last resort	5.52	1538	1173	1	808	1	89

Note. [a]number of days from initial WB to act of violence; [b]number of years from initial WB to act of violence; [c]number of days from initial Leakage to act of violence; [d]number of days from initial Directly communicated threat to act of violence; [e]number of days from last Leakage to act of violence; [f]number of days from last Directly communicated threat to act of violence; [g]number of days from last Leakage or Directly communicated threat to act of violence; [h]total number of all WBs.

Table 2. Initial perception of WBs measured in number of days to act of violence, across all cases ($N = 11$).

	absolute days					z-values					
WB	*min*	*max*	*M*	*MD*	*SD*	*min*	*max*	*M*	*MD*	*MR*	*SD*
Identification	1020	5710	2476.91	1841.00	1337.78	0.79	5.28	2.98	2.45	69.18	1.47
Fixation	865	4749	2682.09	2571.00	1374.51	1.55	7.75	3.13	2.32	69.09	1.85
Novel aggression (n=8)	45	3428	1391.00	1298.50	1278.63	-0.31	3.48	1.29	0.60	47.19	1.58
Last resort	7	4825	1059.18	690.00	1385.25	-0.65	3.79	0.61	0.16	36.59	1.29
Leakage	70	2080	815.55	810.00	736.79	-0.33	1.36	0.35	-0.03	34.77	0.67
Directly communicated threat (n=10)	0	2164	703.40	655.50	705.67	-0.51	1.73	0.28	0.09	31.95	0.74
Pathway	85	2086	760.00	360.00	775.57	-0.33	0.90	0.19	0.17	30.55	0.48
Energy burst (n=10)	1	1237	223.60	38.00	383.85	-0.80	0.53	-0.33	-0.35	14.70	0.37

Note. WB, warning behaviors; min, minimum value; max, maximum value; M, mean value; MD, median; MR, mean rank; SD, standard deviation. Sorted according to descending mean rank of the z-values and colored in time periods (yellow = first, orange = second, red = third).

computed.[1] The initial occurrence of *Identification* and *Fixation* is perceived significantly earlier than any other type of WBs. There is no statistical difference between *Identification* and *Fixation* ($H = 0.09$, $Z = 0.01$, $p_{BH}{}^2 = .99$). The initial occurrence of *Energy burst* is perceived significantly later than any other type of WBs, but only tends to differ from *Directly communicated threat* ($H = 17.25$, $Z = 1.60$, $p_{BH} = .19$) and *Pathway* ($H = 15.85$, $Z = 1.50$, $p_{BH} = .21$). A Mann-Whitney U test with Monte Carlo simulation ($CI = 99\%$, $N = 10{,}000$) showed a significant difference between the initial occurrence of *Pathway* and *Energy burst* ($MR_{\text{Pathway}} = 14.09$, $MR_{\text{Energy Burst}} = 7.60$, $U = 21.00$, $Z = 2.39$, $p = .02$[3]). This leads to a prototypical temporal order of the WBs. It is divided into three time periods. Within these time periods, there is no significant difference between the WBs. This prototypical temporal order is shown in Figure 2.

The frequencies of the WBs are examined. Table 3 shows the frequencies of the perceived WBs. A Kruskal–Wallis test for independent samples shows significant differences between the frequencies of the WBs (absolute frequencies: $H = 50.33$, $df = 7$, $p \leq .001$; relative frequencies: $H = 57.38$, $df = 7$, $p \leq .001$). Pairwise comparisons were computed[1]. *Identification* and *Fixation* are the most frequently perceived types of WBs. This is significant when compared to *Novel aggression (Identification:* $H = 54.09$, $Z = 4.97$, $p_{BH} = .00$; Fixation: $H = 49.46$, $Z = 4.55$, $p_{BH} = .00$), *Directly communicated threat (Identification:* $H = 47.86$, $Z = 4.40$, $p_{BH} = .00$; Fixation: $H = 43.23$, $Z = 3.97$, $p_{BH} = .00$), *Energy burst (Identification:* $H = 44.46$, $Z = 4.09$, $p_{BH} = .00$; Fixation: $H = 39.82$, $Z = 3.66$, $p_{BH} = .00$) and *Leakage (Identification:* $H = 24.46$, $Z = 2.25$, $p_{BH} = .05$; Fixation: $H = 19.82$, $Z = 1.82$, $p_{BH} = .11$). *Novel aggression, Directly communicated threat* and *Energy burst* are perceived significantly less frequently than any other type of WBs. Three categories of frequency are presented in Figure 2.

Table 4 shows the frequencies of WBs in the time period close to the act of violence (6 months) and the frequencies of WBs in temporal occurrence excluding the last time period. A Mann-Whitney U test compared the differences between these two time periods. Three cases (6, 7, 9) were excluded because the last occurrence of *Leakage* and *Directly communicated threat* was perceived significant earlier than in the prototypical temporal order (group comparison $U = .00$, $p = .01$). Before the act of violence, occurrences of *Last resort, Leakage*, and *Energy burst* were significantly more frequent. *Directly communicated threats* have also tended to be significantly more frequent. Two extreme outliers (>3.0 * interquartile range) were identified in the temporal occurrence of *Pathway* (cases 8, 10), which had significantly more total WBs than the other cases ($U = .00$; $p = .04$). If these cases were excluded for the third question, it was found that *Pathway* occurred significantly more frequently close to the act of violence. In Figure 3 the characteristics of the WBs are summarized.

Discussion

With regard to question 1 this study found that the first perception of the WBs occurs in a specific temporal order. Specifically, three time periods of the first perception of the WBs could be identified:

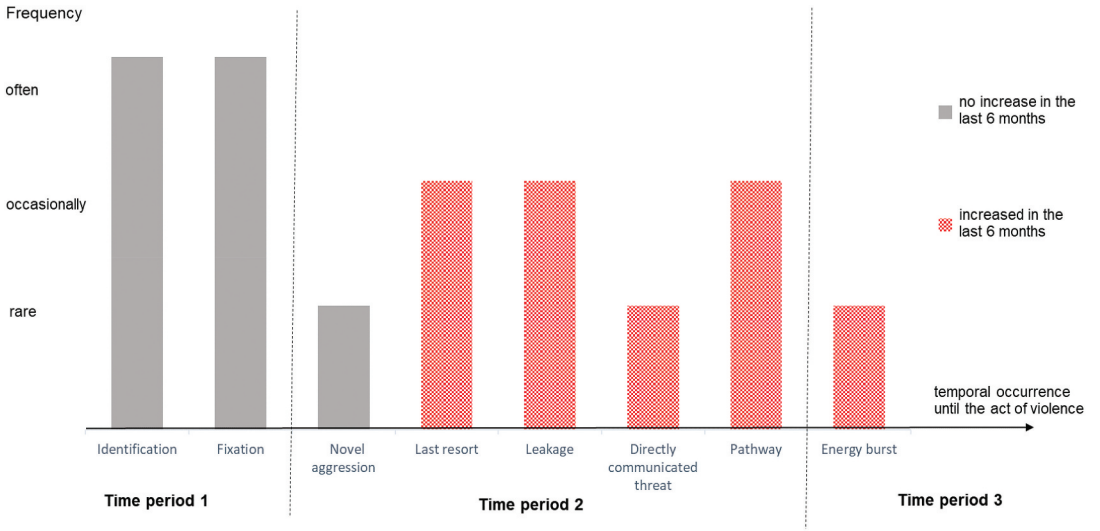

Figure 2. The prototypical temporal order of initial WBs and frequency of WBs.

Table 3. Frequencies of the WBs ($N = 11$).

	absolute frequency						relative frequency				
WB	*min*	*max*	*M*	*MD*	*MR*	*SD*	*min*	*max*	*M*	*MD*	*SD*
Identification	11	57	23.09	21.00	70.23	13.49	0.16	0.32	0.23	0.23	0.06
Fixation	6	55	25.27	17.00	65.59	18.14	0.06	0.44	0.24	0.20	0.10
Last resort	3	19	12.91	14.00	55.64	5.30	0.05	0.24	0.14	0.14	0.07
Pathway	5	46	17.27	10.00	54.50	14.90	0.06	0.26	0.16	0.16	0.07
Leakage	2	19	10.00	10.00	45.77	4.92	0.02	0.27	0.12	0.10	0.07
Energy burst (n=10)	1	14	5.50	4.00	25.77	4.93	0.01	0.11	0.05	0.06	0.04
Directly communicated threat (n=10)	1	11	4.30	3.00	22.36	3.50	0.01	0.11	0.04	0.03	0.04
Novel aggression (n=8)	1	7	3.50	3.00	16.14	2.27	0.01	0.08	0.04	0.04	0.03

Note. WB, warning behaviors; min, minimum value; max, maximum value; M, mean value; MD, median; MR, mean rank; SD, standard deviation.
Sorted according to descending mean rank of the absolute frequencies and colored in three categories (yellow = often, orange = occasionally, red = rare).

Table 4. Absolute frequencies of WBs – comparison between two time periods ($N = 11$).

	Time period excluding last 6 months						Time period close to the act of violence (last 6 months)								
WB	*min*	*max*	*M*	*MD*	*MR*	*SD*	*min*	*max*	*M*	*MD*	*MR*	*SD*	*U*	*Z*	*p*
Identification	**2**	**47**	**16.00**	**12.00**	**14.23**	**13.12**	1	19	7.09	5.00	8.77	5.05	30.50	−1.97	.05
Fixation	0	52	17.27	8.00	12.45	17.61	1	16	7.91	8.00	10.55	5.05	50.00	−0.69	.52
Novel aggression (n = 8)	0	6	2.13	1.50	9.13	2.23	0	3	1.25	1.00	7.88	1.04	27.00	−0.54	.65
Last resort^{+}	0	14	4.64	3.00	9.14	4.91	**2**	**18**	**8.27**	**8.00**	**13.86**	**5.14**	34.50	−1.71	**.09**
Leakage	0	10	3.55	3.00	10.05	3.2	0	16	6.45	6.00	12.95	5.80	44.50	−1.06	.30
Leakage (n = 8)*	0	10	3.13	2.50	5.81	3.52	**1**	**16**	**8.88**	**9.50**	**11.19**	**4.85**	10.50	−2.27	**.02**
Dcr (n = 10)	0	5	1.40	1.50	9.10	1.6	0	11	2.90	2.00	11.90	3.32	36.00	−1.08	.32
Dcr (n = 8)	0	5	1.38	1.00	6.69	1.77	0	11	3.50	3.00	10.31	3.46	17.50	−1.55	.13
Pathway	0	33	7.73	3.00	9.27	12.44	0	20	9.55	10.00	13.73	5.79	36.00	−1.62	.11
Pathway (n = 9)*	0	6	2.22	2.00	6.56	2.34	**0**	**20**	**8.67**	**9.00**	**12.44**	**6.08**	14.00	−2.37	**.02**
Energy burst (n = 10) **	0	4	1.00	0.00	6.80	1.63	**1**	**10**	**4.50**	**4.00**	**14.20**	**3.50**	13.00	−2.86	**.00**
Total	6	138	52.91	39.00	11.36	47.04	9	86	46.91	53.00	11.64	22.39	59.00	−0.10	.95

Note. WB, warning behaviors; Dcr, Directly communicated threat; *min*, minimum value; *max*, maximum value; *M*, mean value; *MD*, median; MR, mean rank; *SD*, standard deviation; *U*, Mann Whitney U test; *Z*, z-value of the Mann-Whitney U test; *p*, exact significance tests (two one-sided tests). The significantly more frequent time period is printed in bold. $+p \le .1$.*$p \le .05$.**$p \le .01$.

Identification	**Fixation**	**Novel aggression**	**Last resort**
Start of the PTO (1. time period)	Start of the PTO (1. time period)	Center of the PTO (2. time period)	Center of the PTO (2. time period)
Often	Often	Rare	Occasionally
No increase in the last 6 months	No increase in the last 6 months	No increase in the last 6 months	Increased in the last 6 months
Leakage	**Directly communicated threat**	**Pathway**	**Energy burst**
Center of the PTO (2. time period)	Center of the PTO (2. time period)	Center of the PTO (2. time period)	Final of the PTO (3. time period)
Occasionally	Rare	Occasionally	Rare
Increased in the last 6 months	Increased in the last 6 months	Increased in the last 6 months	Increased in the last 6 months

Figure 3. Characteristics of the WBs. PTO, prototypical temporal order.

Identification and *Fixation* were coded in the first time period; *Novel aggression, Last resort, Leakage, Directly communicated threat*, and *Pathway* in the second; *Energy burst* in the third.

Meloy, Goodwill, et al. (2021) identified the following temporal sequence of WBs in cases of lone-actor terrorism: (1) Fixation (2) Identification (3) Last resort/Pathway/Leakage (4) Directly communicated threat. Importantly and in contrast to the present study, they used a sequence analysis. Specifically, all available behavioral indicators were formed into "chains" or sequences of behaviors. These behavioral indicators (and hence sequences) were "mapped onto" the specific distal and proximal WBs.

There are some studies which have investigated the behavior of perpetrators of STSV before the act of violence longitudinally without using the concept of WBs by Meloy et al. (2012). For instance, Keatley et al. (2020) studied the behavioral development of 16 US perpetrators and identified five time periods. Silva et al. (2023) found a similar pathway to intended violence in school and college perpetrators, in which, for example, planning behavior appears late on the pathway. Calhoun and Weston (2003) developed the Path to Intended Violence model, which presents six stages that build on each other over time. The findings of the present study are in line with this body of research and extend the findings to the concept of WBs in conjunction with STSV. According to the results presented, there is a diffuse frustration at the beginning of the developmental path of cases investigated, which intensifies and becomes more concrete as it progresses over time. Most of those affected in this form either develop emotional or behavioral outlets during this time period, or they benefit from protective factors that counteract negative development (Silva et al., 2023). If this is not the case, if these are insufficient, respectively, if external stressors persist, or critical negative life events occur, the person of concern has a higher risk to progress along the negative developmental path. As a result, unspecific behavior, which initially occurs in many people, becomes increasingly specific and is gradually exhibited by fewer and fewer people. Similarly, Calhoun and Weston (2003, p. 57) describe targeted violence as a process of "discrete, sequential and recognizable behaviors" that accumulate into a final act of violence if the developmental path is not interrupted.

With regard to question 2 the frequencies of perceived WBs differed between the types of WBs. *Fixation* and *Identification* were coded most frequently in our study; *Energy burst, Directly communicated threat* and *Novel aggression* were coded least frequently; *Pathway, Last resort* and *Leakage* were in between.

We are not aware of any study to date that has examined the absolute and relative frequencies of perceived WBs. However, our findings are consistent with those of Meloy et al. (2014) in that *Pathway, Fixation, Identification*, and *Leakage* are shown by all perpetrators. Not all offenders showed *Novel aggression, Energy burst* and *Directly communicated threats*. Meloy et al. (2014) found that 11% of perpetrators in their study exhibited *Directly communicated threats* compared to 90.91% of the sample in the present study. This may be because we coded all death threats directed at a person, even if the person threatened did not subsequently become the victim of the STSV. This pattern is further corroborated by analyses of WBs in case studies by Erlandsson and Meloy (2018) and Allely et al. (2024). Erlandsson and Meloy (2018) examined a Swedish perpetrator who exhibited all WB except for *Directly communicated threats*, while Allely et al. (2024) analyzed a U.S. case in which all WB were present except for *Novel aggression* and *Energy burst*. In contrast, WBs were not present in all perpetrators examined by Abel et al. (2022) in a U.S. sample of 20 cases. For instance, *Pathway* was

found in only 15.0% of perpetrators, while *Fixation* was found in 5.0%, *Identification* in 25.0%, *Novel aggression* and *Energy burst* in 0.0%, *Leakage* in 65.0%, *Directly communicated threats* in 10.0%, and *Last resort* in 15.0% of perpetrators.

While Abel et al. (2022) found that WBs were not present in all perpetrators, their findings also highlighted considerable variability between cases in terms of the types of WBs exhibited, which aligns with the findings of the present study. The divergent outcomes can be attributed to variations in data sources (public vs. nonpublic data) and potentially cultural factors.

With regard to question 3 some WBs (*Last resort, Leakage, Pathway, Energy burst* and a tendency for *Directly communicated threat*) are perceived more frequently close to the act of violence than throughout the temporal occurrence excluding the last time period. These findings were consistent with those of Meloy et al. (2012) who postulated that *Energy burst* occurs in the last days and weeks before the act of violence. This finding is also consistent with the research findings of Abel et al. (2022), which reported that the majority of WB were found shortly before the crime.

To sum up, the present study shows that *Fixation* and *Identification* are perceived earliest and most frequently. Compared to the other WBs, they are more temporally distal. *Energy burst* is perceived rarely, late and more frequently close to the act of violence. In the sample of cases investigated in the present study, *Energy burst* and the cumulative occurrence of *Last resort, Leakage, Pathway* and *Directly communicated threats* are close in time to the act of violence.

Additionally, in all cases investigated, there is evidence of a years-long pathway to intended violence consistent with previous findings (e.g., Fein et al., 2002).

In each case investigated, WBs were already perceived before the initial *Leakage* or *Directly communicated threat* occurred. It may be that *Leakage* and *Directly communicated threats* are an expression of an already emerging negative pathway to intended violence. Based on the findings of this study, it is strongly recommended that practitioners initiate their threat assessment and management at this point.

In the majority of cases, the perpetrators made *Leakage* or *Directly communicated threat* up to the day of the act of violence or up to one day before the act of violence, respectively. In three out of 11 cases (cases 6, 7, 9), the last *Leakage* or *Directly communicated threat* was made with distance from the act of violence. This is in accordance with Sommer et al. (2020), who showed that there are two different strategies for later perpetrators of STSV to cope with shame: internalized strategies (e.g., social withdrawal) and externalized strategies (e.g., aggressive behavior). It can be concluded that the person of concern still plans to commit an act of violence – but may no longer inform others about it.

We found that a wider psychosocial context, e.g., further information about thoughts, feelings and current crises, is often necessary in order to recognize a certain behavior as a WB. Then, the intentions of the perpetrator and their pathway to intended violence become evident in many of the cases investigated. In this study, a high number of WBs were perceived by others. However, in line with the literature (Fiedler et al., 2020), they do not react or may even react counterproductively. A reason might be that most WBs lack a distinctive appearance to indicate a crisis. For instance, a psychosocial crisis may not be recognized when passive behavior resulting from frustration and hopelessness is observed (Fiedler et al., 2020). The behavior is not evaluated as an alarm signal. In the cases investigated, 37% of the WBs were perceptible but not perceived. This highlights several other opportunities to identify a psychosocial crisis in the persons of concern.

Implication for practice and prevention

The present study shows that signs of a psycho-social crisis can be observed at an early stage. It is therefore suggested to implement preventive measures at an early stage in order to be able to react to these signs. This may prevent a person entering a pathway to intended violence (Fiedler et al., 2020). We recommend to establish networks that integrate information from multiple sources (e.g., peers, teachers, parents). This information should be evaluated by multiple individuals who are trained in the threat assessment process. Programs that can assist with this and support the management of the

threats include the School Threat Assessment Toolkit (Cornell & Maeng, 2024) and the Networks Against School Shootings (NETWASS) prevention program (Leuschner et al., 2017). The programs support schools in establishing these structures and provides knowledge to conduct well-founded threat analyses.

Threat assessment must be systematically integrated across institutions, extending beyond terrorism to school-related cases. Effective assessment requires collaboration between key stakeholders, including educational institutions, law enforcement, and specialized threat assessment teams. It is essential to establish dedicated, well-trained teams that work closely with these entities as well as health authorities. When *Leakage* or *Directly communicated threats* are identified, a multi-stage monitoring process should be initiated to systematically collect, chronologically document, and evaluate existing information. Without access to necessary data, due to privacy restrictions, threat and risk assessment cannot function. The objective is not just to prevent a single act of violence but to establish a proactive system that identifies and disrupts the pathway to intended violence early, enabling institutions to implement effective threat management.

Studies analyzing thwarted acts of violence suggest that many of them could have been avoided by adequately recognizing and dealing with WBs. Silva and Greene-Colozzi (2022) investigated thwarted STSV in the US and found that 65% were based on *Leakage* by the perpetrator. Winch et al. (2024) showed that a greater frequency of *Leakage* is found in thwarted acts of STSV than in completed acts of STSV. The authors conclude that perpetrators have also shown *Leakage* in the forefront of the STSV, but that this information was less often passed on and thus less often considered.

Limitations and future research directions

The concept of WBs was developed based on US cases. It is important to note that these may not be entirely applicable to situations in other countries. This difference may be due to cultural factors, or to variations in gun laws – beside others. Time-related differences may also be a reason why German cases from the 1990s and current cases from the US cannot be transferred using the same coding tool. A comparison of cases and an internationally valid coding tool would be desirable.

In further analyses, we will conduct a temporal sequence analysis based on STSV. Figure 1 of this study raises further questions, e.g., do the interventions and reactions influence the pattern of perceived WBs? Are there differences in the cases in which the WBs accumulate close to the act of violence? What conclusions can be drawn regarding the effectiveness of different interventions and reactions? These questions need to be investigated in further studies.

The small sample size investigated in the present study represents a phenomena-related challenge. The coded behaviors, the coding of behaviors, respectively, may be influenced by biases. The observed behavior should be remembered, reported to the police and documented by them. It is reasonable to assume that a significant portion of perceived WBs was not included in these analyses. It is likely that the perceived WBs are also influenced by other factors (severity of the act of violence, survival of the perpetrator, media attention, availability of diaries and other material from the perpetrator). These factors, in turn, may also affect the investigation. The statements recorded by the police may be prone to error as they are subjective. The material was coded independently by two of the authors in order to reduce any potential bias. This analysis provides a minimum and approximate value of the true value based on the investigation files.

To date, WBs have only been measured in violent perpetrators. There is a lack of studies on the occurrence of such behavior in the general population. To evaluate the specificity and prognostic value of the WBs (e.g., related to threat assessments of possible shooters), representative studies investigating school populations are needed. Also, further research is needed to determine if the differences between self-initiated terrorism and STSV can be replicated and to determine the prevalence of WBs in other populations.

Despite differences within the 11 German cases examined here, there are notable overlaps with international cases. For example, many subsequent acts (also in Germany) after the school shooting in

Columbine deliberately refer to this act and there are references and similar narratives in the sequences of later acts. Consequently, we assume that the findings derived from the German cases can be transferred to international ones. Nevertheless, there are also differences when we look at the course of events, backgrounds, etc., so that we can learn from international comparisons and case analyses. The results of the German cases presented here therefore allow comparisons to be made with international cases.

In this study, we focus on a new methodology, research approach, respectively, in analyzing case data. We demonstrated the efficacy of this approach, and it is now recommended that it be applied to a broader range of cases and phenomena. To our knowledge, we are the first to apply this method, and an important question is to what extent it can be transferred to international cases. Future research would benefit from comparisons with U.S. cases to analyze country-specific factors such as gun laws, firearm attitudes, and school systems, helping to identify key similarities and differences.

Notes

1. A list of the individual pairwise comparisons can be provided.
2. Benjamini and Hochberg (1995) procedure as adjusted significance
3. Due to the disadvantages of the bootstrapping procedure, this method was only used for this pair comparison.

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Data availability statement

Anonymous data in this study is available upon request to the corresponding author. The datasets analyzed for this study, i.e., original inquiry files from law enforcement authorities, cannot be shared for legal and privacy restrictions.

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Appendix. Case examples for each WB

Pathway - Repeatedly asks another person for access to a shooting range, inquires about the possession of a firearm, its storage location, and how ammunition is obtained; Documents a list of individuals as potential targets

Fixation - Writes to someone: 'Nobody truly needs me at all, and I just can't take it anymore - being absolutely useless, basically not even existing, and always just being a piece of dirt.'; Reports planning to take revenge and kill everyone, stating that the teachers are to blame for this fate

Identification - Wrote specific torture fantasies in a diary, describing how a person is drilled into and tormented; Posts a public comment on social media under a video about a perpetrator, expressing approval of the act

Novel aggression - Hits mother in the face for the first time; Holds a gas pistol to someone's head

Energy burst - Suddenly becomes much more engaged in class; Contrary to usual withdrawn behaviour; suddenly becomes very restless

Leakage - Started talking about what it would be like to carry out an STSV. Described the plan in detail, stating the intention to build Molotov cocktails; Speaks enthusiastically about a perpetrator and states the intention to carry out something similar in 1–2 years

Last resort – Tells another person about the intention to throw a big farewell party and asks them to bake a cake; Suddenly gives away multiple personal belongings over the course of a weekend

Directly communicated threat - Says to a teacher: 'You stupid son of a bitch, I will kill you!'; Tells classmates that they may not be alive for much longer.