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THE *SOUNDRISE* ALARM: THE IMPACT OF A GRADUALLY RISING ALARM ON MORNING MOOD AND WAKING-UP BEHAVIOR

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Abstract

This study examined whether a gradually rising pre-wake alarm affects the morning awakening experience differently from a sustained version of the same alarm. In a 14-night home-based within-subjects study, 18 participants experienced both alarm conditions and reported morning states and waking-up behavior. The gradually rising alarm was associated with significantly higher morning positive affect and longer alarm stop time, and with no significant differences in sleepiness, perceived sleep quality, snooze use, or waking-up delay. Associations between pre-sleep states and morning mood were also generally weaker under the gradually rising condition. These findings suggest that a gradually rising alarm may improve the sleep-to-wake transition and support a smoother, more positive awakening.

Keywords: *pre-wake alarm sound, awakening, morning mood, sleep*

1. Introduction

In the last few decades, consumer sleep technologies have rapidly developed in popularity, however there is limited evidence of their effectiveness and mechanisms, particularly for improving the awakening process [1]. Within this context, sound is promising as a non-pharmaceutical, low-cost deployable medium for affecting sleep and awakening. Sleep neurophysiology further supports the plausibility of using sound to influence sleep and awakening. Previous research shows that auditory processing remains active during sleep, although in an attenuated form. The sleeping brain continues to monitor external sounds, and auditory stimulation can interact with ongoing sleep dynamics by evoking thalamocortical responses, triggering K-complexes, and modulating slow-wave-related activity [2], [3], [4], [5]. Some forms of sound stimulation have also been shown to enhance slow-wave activity and to improve autonomic state after morning awakening [6]. Consistent with this mechanistic account, applied studies in real-world settings suggest that different forms of sound can alter sleep experience and stability: masking sounds can reduce noise-related sleep disruption, pink noise can promote more stable sleep, and music-based interventions can facilitate relaxation and support sleep quality in specific contexts [7], [8], [9], [10], [11], [12]. This perspective is particularly relevant to the design of alarm sounds. Research suggests that natural sounds produce less physiological stress than harsh alarms, while melodic alarms improve alertness, post-waking performance, and reduce sleep inertia [13], [14], [15]. In addition to sound type and melodic content, alarm sounds can also vary in how they unfold over time. In the present study, we focused on one such temporal design feature: a gradually intensifying pre-wake alarm, intended to increase arousal level slowly during a five-minute transition window before full awakening. We present a user study that examined whether this gradual pattern differs from a steady-intensity pattern in its effects on the awakening experience, including factors such as subjective sleepiness, emotional state, perceived sleep quality, and wake-up behavior.

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2. Method

2.1. Alarm Sound Design

The rising version of the SoundRise alarm was designed following guidelines for low-intrusiveness sound [16]. Two groups of sinusoids (A and B) play together. Group A continuously plays back the following pitches: D3,F3,C4,F4,G4,E5. Group B plays back a descending glissando from D#3,F#3,C#4,F#4,G#4,F5 to D3,F3,C4,F4,G4,E5. This creates an initial roughness, gradually resolving into a consonance. Both groups are also frequency-modulated- group A progressively from 200Hz to 0Hz, and group B from 200Hz to 0Hz (i.e. inharmonic to harmonic). A slow amplitude modulation is applied to the mix of the two groups, slowly progressing from a period of 8 seconds (50% intensity) to 4 seconds (100% intensity). Finally, the output volume evolves from -30 dB to 0 dB, following an exponential curve. The resulting sound is characterized by a gradual increase in intensity, a decrease in dissonance, roughness and inharmonicity, and a slight acceleration and intensification of the slow internal pulsation. The sustained version of the SoundRise alarm plays continuously the last event of the rising alarm (i.e. the louder, less dissonant event). Audio examples of both the gradually rising and sustained versions of the SoundRise alarm are available at `https://youtu.be/_uw2g1eIaXs`.

2.2. Study Procedure

We conducted a two-week home-based within-subject study to compare two *SoundRise* alarm conditions: a gradually rising-in volume and sonic density-alarm and a sustained version of the same alarm. The order of conditions was counterbalanced across participants. Before the study, participants completed a background questionnaire on demographics, sleep habits, and habitual alarm use. For each condition, two calibration nights were used for familiarization and volume adjustment, followed by five main study nights in the participants' natural sleep environment. The alarm setup consisted of a pre-wake SoundRise sound followed by a standardized backup wake-up alarm. Participants completed a structured morning questionnaire within two hours after awakening each day. After completing both alarm conditions, participants also completed a brief follow-up questionnaire about whether they continued using the SoundRise alarm after the study, along with brief open-ended questions.

2.3. Measures

The morning questionnaire assessed pre-sleep state, subjective sleep quality, morning awakening state, and wake-up behavior. Pre-sleep state was measured using three single-item ratings on 7-point Likert scales of cognitive arousal, somatic arousal, and perceived daily stress, with the arousal items adapted from the cognitive and somatic constructs of the Pre-Sleep Arousal Scale (PSAS) [17], together with a single-item rating of perceived daily stress [18]. Subjective sleep quality was assessed with a single global item on a 7-point scale [19]. Morning awakening state included sleepiness measured with the Karolinska Sleepiness Scale (KSS) [20], along with single-item ratings of mood and stress. Wake-up behavior included whether participants noticed the pre-wake SoundRise alarm, whether snooze was used, and two measures of post-alarm behavior: alarm stop time, grouped into ordered delay intervals from immediate stopping to longer delays, and getting up later than planned, grouped into ordered categories ranging from on time or earlier to increasingly longer delays.

The full questionnaire is available in Zenodo [10.5281/zenodo.19119387].

3. Participants

Nineteen participants enrolled in the study and completed a questionnaire on personal information and sleep habits. One participant did not complete the full protocol and was subsequently excluded.

3.1. Participant background and sleep habits

The final sample of 18 participants (10 female, 8 male) ranged in age from 22 to 63 years ($M = 27.83$, $SD = 9.36$, $Mdn = 25$). Participants came from various countries and regions, with the majority having spent most of their life in China ($n = 8$) or Sweden ($n = 3$). Seventeen participants reported normal hearing; one reported reduced hearing in one ear.

Based on self-reports for the month prior to the study, participants' average habitual sleep duration was 7.69 hours per night ($SD = 0.99$, ranging from 6 to 10 hours). Most participants rated their overall sleep quality as fairly good or very good ($n = 16$), while two rated it as fairly bad. Smartphone alarms were most common ($n = 16$), and most participants used an alarm at least four days per week and normally had snooze enabled (both $n = 15$). Participants did not normally use a gradually increasing alarm, indicating that this condition was novel for the majority.

3.2. Study data and analytic sample

The 18 participants generated 246 morning questionnaire responses across the 14-day study period. Before analysis, responses from the two-night habituation and calibration period were excluded ($n = 73$). Nights when the alarm had no effect, including when participants reported awakening before the alarm or when the alarm app did not function as intended, were excluded ($n = 28$). One duplicate submission was removed.

The final analytic sample consisted of 144 valid observation nights, and all subsequent analyses were based on these observations. Each participant contributed between 6 and 10 valid nights ($M = 8.0$). Within this final sample, 75.7% of nights ($n = 109$) were spent sleeping alone, and most nights were reported as not having been affected by unusual circumstances ($n = 113$, 78.5%). This information provides general context about the sleeping conditions under which the study was conducted. The SoundRise alarm was heard on most nights ($n = 135$, 93.8%). Participants reported being awakened by the SoundRise alarm itself on 84.7% of nights ($n = 122$). Snooze or equivalent delay methods were used on 20.8% of nights ($n = 30$).

4. Result

4.1. Morning States

To examine condition differences in morning outcomes, we conducted paired Wilcoxon signed-rank tests at the participant level, and additionally performed a night-level paired analysis as a supplementary check to assess whether a similar pattern was observable when retaining night-to-night variation.

At the participant level, we adopted a two-stage approach: for each participant, mean scores were computed within each condition (raising and steady), and participant-level difference scores (raising − steady) were then tested against zero using Wilcoxon signed-rank tests. This analysis showed that participants reported significantly higher positive mood scores (Happy) when using the gradually increasing alarm than the sustained alarm ($W = 121$, $p = .007$). No significant participant-level differences were found for morning sleepiness as measured by the Karolinska Sleepiness Scale (KSS; $p = .394$), perceived sleep quality ($p = .356$), morning stress ($p = .088$), or subjective alarm pleasantness ($p = .147$), although morning stress showed a higher, but non-significant score for calmness in the gradually increasing condition ($p = .088$).

We also analyzed the raw nightly paired observations in order to retain night-to-night variation in sleep and waking experiences. This night-level analysis showed the same overall pattern: mood again differed significantly between conditions ($W = 429.00$, $p = .013$), whereas KSS ($W = 634.50$, $p = .127$), morning stress ($W = 588.50$, $p = .178$), and sleep quality ($W = 932.50$, $p = .376$) did not. Across both analytic levels, the results converged in indicating a benefit of the gradually increasing alarm for morning mood, while providing no clear evidence of condition differences for the other outcomes.

4.2. Wake-up Behavior

Regarding post-alarm behavior, participants took significantly longer to stop the gradually increasing alarm compared to the constant-volume alarm (M = 2.17 vs. 1.70 on the 1–4 ordinal scale; Wilcoxon W = 134, p = .007). Despite this longer alarm engagement, neither snooze usage rate (M = 0.20 vs. 0.24, p = .682) nor final wake-up delay (M = 1.28 vs. 1.18 on the 0–3 scale, p = .501) differed between conditions, suggesting that participants who took longer to stop the gradually increasing alarm did not subsequently delay getting up.

4.3. Associations Between Pre-Sleep States and Morning Outcomes

To examine whether the alarm condition altered the relations between pre-sleep states and morning outcomes, Spearman correlations were conducted separately for the steady and rising conditions (see Table 1).

Overall, associations were generally stronger in the sustained condition, while in the gradually rising condition associations diminished, with the most significant reductions noted for morning mood and, to a lesser degree, morning stress. Specifically, for pre-sleep cognitive arousal, significant correlations with morning stress and sleep quality were found in both conditions, with similar correlation magnitudes (steady: $\rho = .491$, $p < .001$; raising: $\rho = .414$, $p < .001$; steady: $\rho = -.303$, $p = .010$; raising: $\rho = -.308$, $p = .009$), indicating that the correlations involving this dimension were relatively consistent across the two alarm conditions. In contrast, a significant correlation with morning mood was only observed in the sustained condition ($\rho = -.269$, $p = .023$), while it was not present in the gradually rising condition ($\rho = .001$, $p = .992$).

By comparison, pre-sleep somatic arousal showed clearer differences between conditions. In the sustained-volume condition, these scores were significantly correlated with morning mood, morning stress, and sleep quality ($\rho = -.432$, $.622$, and $-.504$, respectively). In the gradually rising condition, however, all of these correlations were reduced producing a non-significant correlation with morning mood was no longer significant ($\rho = -.124$, $p = .301$), a decreased correlation with morning stress from strong to moderate ($\rho = .330$, $p = .005$), and a similar decreased correlation for sleep quality ($\rho = -.270$, $p = .022$). A similar pattern was observed for perceived stress of the day. In the sustained condition, perceived stress of the day was significantly correlated with morning mood, morning stress, and sleep quality ($\rho = -.349$, $.438$, and $-.323$, respectively). In contrast, in the gradually rising condition, only the correlation with sleep quality remained significant, and this correlation was weaker ($\rho = -.248$, $p = .036$); the correlations with morning mood and morning stress were no longer significant.

Overall, the correlation patterns differed by alarm condition. Associations between pre-sleep states and morning outcomes were generally more widespread and stronger in the steady alarm condition, whereas several of these associations were attenuated or no longer significant in the gradually rising alarm condition, particularly for morning mood and, to a lesser extent, morning stress.

4.4. Post-Study Alarm Adoption and Subjective Experience

A follow-up questionnaire was completed by 12 of the 19 enrolled participants approximately two weeks after the study ended. Four participants reported continuing to use the SoundRise alarm after the study, while eight did not. Across both groups, descriptions of the wake-up experience were mostly positive. Multiple participants ($n = 8$) characterized waking up with SoundRise as gentle and non-startling: one person described being able to “start my day more relaxed, not stressing from alarm,” while another reported the experience as “feeling awake smoothly.” A recurring observation was that the alarm functioned effectively despite its low intrusiveness, with one participant noting that they “cannot notice that the alarm is ringing, but somehow always manage to wake up”. One participant reported feeling “relaxed or joyful” upon waking up, and another described the overall experience as “very comfortable.” A minority of participants ($n = 2$) reported a more neutral experience, describing it as functional, but unremarkable. When comparing the SoundRise alarm to their habitual alarm ($n = 6$), participants frequently contrasted the gradual or soft onset with the abrupt and loud character of

Table 1: Associations Between Pre-Sleep States and Morning Outcomes by Alarm Condition (Spearman Correlations)

Predictor	Outcome	Sustained		Raising	
		ρ	p	ρ	p
Pre-sleep Cognitive Arousal	KSS (Sleepiness)	0.002	.986	0.091	.509
	Morning Mood	−0.269	.023*	0.001	.992
	Morning Stress	0.491	< .001***	0.414	< .001***
	Sleep Quality	−0.303	.010*	−0.308	.009**
Pre-sleep Somatic Arousal	KSS (Sleepiness)	−0.064	.596	0.005	.964
	Morning Mood	−0.432	< .001***	−0.124	.301
	Morning Stress	0.622	< .001***	0.330	.005**
	Sleep Quality	−0.504	< .001***	−0.270	.022*
Perceived Stress of the Day	KSS (Sleepiness)	−0.166	.166	−0.032	.790
	Morning Mood	−0.349	.003**	−0.030	.800
	Morning Stress	0.438	< .001***	0.154	.196
	Sleep Quality	−0.323	.006**	−0.248	.036*

Note. ρ = Spearman correlation coefficient. * $p < .05$. ** $p < .01$. *** $p < .001$.

their usual alarm. Habitual alarms were described as "much louder and more like a horn sound," "much more annoying and startling," and producing a "noisy or strong sound at the beginning." One participant, who returned to a default system alarm after the study noted that even vibration alerts now felt "kind of aggressive," suggesting a perceptual recalibration following exposure to the SoundRise sounds.

5. Discussion

The present study examined whether a gradually rising pre-wake alarm was associated with different morning awakening experience and wake-up behavior compared to a sustained version of the same alarm in a 14-night in the home within-subjects design. The findings suggest that the effect of the gradually rising alarm can affect the transition to wakefulness. Participants reported significantly better morning mood under the gradually rising condition. Additionally, alarm stop times were significantly longer, whereas snooze use and wake-up delay did not differ between conditions. In addition, the relationship between pre-sleep states and next-morning experience differed across alarm conditions, with the clearest difference observed for morning mood, where associations with pre-sleep activation weakened (became non-significant) under the gradually rising condition. Taken together, the results are more consistent with an effect on awakening transition than with an effect on perceived sleep itself.

5.1. Gradual Awakening and Morning Positive Affect

A central finding of the study was a small but significant improvement in morning mood under the gradually rising volume condition (W = 121, p = .007, r = .64), an effect observable in both the participant-level aggregated analysis and in the night-level paired analysis. Morning sleepiness, perceived sleep quality, and morning stress did not differ significantly between conditions, but morning stress showed a directional tendency in the expected direction, with lower values under the rising condition (p = .088). Taken together, this pattern indicates that the acoustic profile of the alarm was more clearly associated with positive affect at wake onset than with subjective sleepiness or retrospective sleep evaluation.

One interpretation is that the gradually rising alarm produced a less abrupt sleep-to-wake transition, reducing the acute affective cost of externally forced awakening. This interpretation is consistent with prior evidence that more abrupt alarm-driven awakenings are associated with greater cardiovascular and neuroendocrine activation at wake onset, whereas gradual alerts can attenuate acute heart-rate responses [21], [22], [23]. It is also compatible with research showing that external sounds continue to be processed during sleep, with responses shaped by ongoing sleep dynamics and auditory arousal thresholds, such that a gradually rising alarm may better accommodate sleep state and allow awakening to unfold more progressively [2], [3], [4], [5], [24].

Participants' qualitative responses in the post-study follow-up questionnaire provide partial support for this interpretation. Several participants described the pre-wake SoundRise alarm as supporting a smoother awakening experience. However, most did not clearly attribute this impression specifically to the gradually rising versus sustained version of the alarm. These reports suggest that smoother awakening was a meaningful experiential dimension in the study context. In this sense, the qualitative feedback is consistent with the quantitative finding that the gradually rising alarm was associated with better morning mood, even if participants were not always explicitly aware of the cause of the difference.

5.2. Extended Alarm Stop Time Without Increased Behavioral Delay

The rising condition was associated with significantly longer alarm stop times (p = .007), suggesting that waking up under the rising alarm unfolded over a longer period. One straightforward explanation is built into the alarm design itself: because the rising alarm begins at a low volume and sonic density and gradually increases to its target level, it may create less pressure for an immediate response than a fixed-intensity alarm. At the same time, this longer alarm stop time did not result in greater snooze use or wake-up delay, suggesting that although participants remained engaged with the alarm for longer, this did not translate into greater behavioral delay.

Together with the more positive morning mood observed under the rising condition, this behavioral pattern is compatible with a less abrupt, improved subjective awakening transition. Prior research suggests that abrupt awakening, especially from deeper sleep, can intensify sleep inertia and increase the desire to return to sleep [25]. Our observations in this study suggest the hypothesis that the temporal and sonic density profile of an alarm may influence the post-awakening recovery processes associated with sleep inertia. Future studies could examine this hypothesis by combining subjective awakening measures with objective post-awakening performance measures such as a Psychomotor Vigilance Test (PVT).

5.3. Attenuation of Pre-Sleep State Carry-Over Under the Gradually Rising Alarm

A third finding concerns how pre-sleep states were associated with the next-morning experience. The clearest condition difference emerged for morning mood: across cognitive arousal, somatic arousal, and perceived daily stress, associations with next-morning mood were consistently weaker and correlations not-significant under the gradually rising alarm than under the sustained-volume alarm. This pattern is compatible with prior work on overnight emotional continuity, which suggests that affective states can persist across the night and affect morning emotion [26], and with evidence that higher pre-sleep arousal is linked to poorer subsequent affective experience [27]. In the present study, the more abrupt onset of the sustained alarm may have preserved the carry-over of prior-night activation into the waking moment, whereas the gradually rising alarm may have supported a gentler transition that reduced how strongly pre-sleep activation was reflected in morning mood. The pattern was less consistent for other outcomes, suggesting that the influence of alarm profile may be most evident in the affective experience at wake onset rather than across all morning measures.

6. Conclusion

The present findings suggest that a gradually rising pre-wake alarm may improve the quality of the waking transition rather than broadly altering sleep-related outcomes. Compared with a sustained version of the same alarm, the rising alarm was associated with more positive mood, and longer alarm stop time, without increasing snooze use or wake-up delay. The weaker associations between pre-sleep states and morning mood under the gradually rising condition further suggest that alarm design may shape how strongly prior-night states carry over into the morning experience. Together, these results indicate that the temporal dynamics of an alarm sound may play a meaningful role in supporting a smoother and more positive awakening in everyday settings. Future work could investigate these effects further with larger studies that utilize both subjective and objective measures.

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