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Interaction Design of Multimodal Sleep Aid Glasses for Young Adults: A User-Needs-Driven Approach

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Abstract: Young adults' sleep is shaped by delayed schedules, digital-media use, and environmental disturbances. Existing sleep-aid products often use a single modality, while evidence on coordinating visual, auditory, and tactile feedback across sleep contexts remains limited. The study surveyed users aged 18–35 about home, dormitory, and travel disturbances, product pain points, feedback preferences, and product-form acceptance. Of 200 questionnaires, 182 were valid (91%). Overall, 65.9% of respondents usually fell asleep after midnight, and 61.0% averaged no more than 7 hours of sleep. The highest-rated functions were auditory fade-out (M=4.27), visual dimming with automatic shutoff (M=4.23), and stage-based feedback reduction (M=4.17). By contrast, simultaneous activation of all three modalities scored 3.34. The study translates these findings into five principles: context adaptation, low stimulation, progressive attenuation, user control, and comfort and safety. The resulting framework links sleep scenarios to user needs, multimodal strategies, and product modules. The study provides an evidence-traceable design approach for non-pharmacological sleep-aid wearables but does not establish objective sleep improvement.

Keywords: Young users; Sleep-aid glasses; Multimodal feedback; Sleep scenarios; Wearable products; Interaction design

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1. Introduction

Adults generally require 7–9 hours of sleep per night, and persistent sleep restriction is associated with physical and mental health risks [1–2]. Young adults also face unstable schedules, work or study pressure, digital-media use, and changing residential environments [3–6]. Sleep-aid products must therefore address both individual routines and context-specific disturbances.

Non-pharmacological sleep support includes psychological and behavioral interventions, light regulation, auditory stimulation, and wearable devices [7]. Evidence for blue-light-filtering glasses and

auditory interventions remains heterogeneous and depends on product parameters and study design [8–10]. Wearable feedback may help in some settings, but outcomes vary with content, delivery, and user differences [11–12]. These findings caution against treating a single technology as a stable therapeutic benefit.

Multimodal human-computer interaction coordinates several perceptual channels [13–15]. Sleep support is a low-arousal context, so excessive light, continuous sound, or strong vibration may be counterproductive. Effective multimodality therefore requires temporal coordination, adjustable intensity, and clear exit mechanisms. Research has rarely translated young adults' context-specific visual, auditory, and tactile preferences into product design rules.

This study asks: RQ1: Which disturbances and needs characterize home, dormitory, and travel sleep contexts? RQ2: How do young users evaluate visual, auditory, tactile, and combined feedback? RQ3: How can survey evidence be translated into design principles, interaction strategies, and product modules? The study addresses design translation rather than clinical efficacy.

2. Research methods

2.1. Participants and research process

The study used an exploratory design pathway: user-need identification, descriptive analysis, design-opportunity extraction, and interaction-strategy translation. The target age range was 18–35 years. Of 200 questionnaires, 182 met the age criterion and were analyzed, giving a 91% valid-response rate. Participants aged 18–24, 25–29, and 35 represented 47.8%, 33.5%, and 18.7% of the valid sample, respectively. Students accounted for 41.8%, corporate employees for 37.9%, and other occupations for 20.3%.

2.2. Questionnaire design and basis for the measures

The questionnaire covered demographics, sleep duration and onset, disturbances at home, in dormitories, and during travel, pain points of existing products, feedback preferences, preferred modality combinations, and product-form acceptance. Sleep-related items were informed by PSQI dimensions, but the instrument was not a standardized PSQI and was not used for diagnosis [16]. Feedback items operationalized low stimulation, adjustability, and automatic stopping to assess design acceptance rather than medical efficacy.

2.3. Data processing and design translation methods

Likert items used a 1–5 scale from strongly disagree to strongly agree. Multiple-choice items yielded selection proportions. Frequencies, percentages, means, and standard deviations supported descriptive analysis. Because the questionnaire combined several need modules rather than one latent scale, Cronbach's alpha and KMO were not primary outcomes. The study cross-synthesized frequent scenario problems, highly rated needs, and form preferences into an evidence-need-principle-strategy mapping (**Figure 1**).

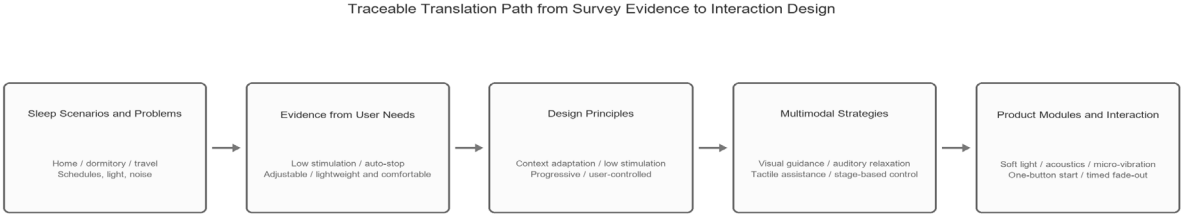

Figure 1. User-needs-driven design translation model for multimodal sleep-aid glasses

3. Survey results

3.1. Sleep duration and scenario disturbances

Among valid respondents, 25.3% reported 5–6 hours of sleep, 26.9% reported 6–7 hours, and 8.8% reported less than 5 hours; 61.0% therefore averaged no more than 7 hours. Moreover, 47.3% usually fell asleep between 24:00 and 02:00, and 18.7% after 02:00. At home, work or study pressure (M=3.92) and electronic-device use (M=3.90) ranked highest. Dormitory users emphasized inconsistent schedules (M=4.06) and light or screen disturbance (M=4.02). During travel, irregular timing (M=4.08) and surrounding noise (M=4.05) dominated. Needs therefore varied across contexts.

3.2. Preferences for the three feedback modalities

Visual items favored low-stimulation, adjustable feedback with automatic shutoff. Natural sounds scored 4.12, while auditory fade-out scored 4.27 (**Table 1**). Tactile acceptance was lower than visual and auditory acceptance, but users valued adjustable vibration and automatic stopping. Simultaneous activation of all modalities scored 3.34, compared with 4.17 for stage-based reduction. Users thus preferred coordinated, attenuated feedback over continuous stimulation.

Table 1. Ratings of representative multimodal feedback items

Feedback modality	Representative item	Mean	Standard deviation
Visual	Gradually dims and turns off automatically	4.23	0.68
Visual	User-adjustable brightness	4.08	0.67
Auditory	Sound gradually fades and stops	4.27	0.71
Auditory	User-adjustable sound type and volume	4.20	0.71
Tactile	User-adjustable vibration intensity	4.03	0.80
Tactile	Vibration stops automatically	4.06	0.76
Combination	Feedback is reduced according to stage	4.17	0.71

3.3. Feedback combinations and product acceptance

The most selected combination was visual, auditory, and tactile feedback (29.1%), followed by visual-auditory (19.2%), auditory-only (17.6%), and auditory-tactile feedback (16.5%). These choices indicate interest in multichannel capability, not continuous concurrent operation. Mean ratings were 4.03 for trial willingness, 3.79 for scenario suitability, 3.75 for one-week use, and 3.86 for purchase at a reasonable price. Key form requirements were lightweight construction (84.6%), adjustable intensity (76.4%), ergonomic comfort (76.4%), non-interference with sleep (75.8%), and one-button operation (65.9%).

3.4. Mapping user needs to design opportunities

Table 2 shows the mapping of user needs, design principles, and interaction opportunities.

Table 2. Mapping of user needs, design principles, and interaction opportunities

Survey evidence	Interpretation of need	Design principle	Interaction/product opportunity
Inconsistent dormitory schedules: 4.06; light disturbance: 4.02	Substantial differences in shared living environments	Context adaptation	Dormitory mode reduces light leakage and sound disturbance

Survey evidence	Interpretation of need	Design principle	Interaction/product opportunity
Irregular sleep during travel: 4.08; noise: 4.05	Rapid adaptation is needed in unfamiliar environments	Context adaptation	Travel preset, quick start, and timed shutoff
Automatic visual shutoff: 4.23; sound gradually fades and stops: 4.27	Avoid continuous stimulation	Low stimulation/user control	Gradually reduce brightness and volume; set a stop time
Feedback reduced by stage: 4.17; three modalities active simultaneously: 3.34	Temporal coordination is preferred over superposition	Progressive feedback	Staged control for sleep preparation, relaxation, and the period after expected sleep onset
Lightweight design: 84.6%; comfortable design: 76.4%	Sensitivity to the burden of prolonged wear	Comfort and safety	Lightweight frame, reduced temple pressure, and side-sleeping compatibility

4. Design translation

4.1. Design principles

Table 2 yielded five principles. Context adaptation assigns distinct presets to home, dormitory, and travel. Low stimulation limits brightness, sound level, and vibration intensity. Progressive feedback attenuates stimuli and turns off major channels after a preset period. User control permits modality, intensity, and stop-time selection without relying on unvalidated sleep-stage detection. Comfort and safety prioritize a lightweight frame, reduced temple pressure, side-sleep compatibility, and active shutoff for auditory and tactile modules.

4.2. Staged multimodal interaction strategy

The strategy uses a user-configurable timed process rather than automatic light/deep-sleep identification (**Table 3**). Current evidence cannot validate sleep-stage detection, so the concept does not present that function as implemented. This boundary prevents overstatement while keeping the interaction logic aligned with the survey.

Table 3. Staged multimodal interaction strategy

Use stage	Visual feedback	Auditory feedback	Tactile feedback	Design purpose
Sleep preparation	Warm, low-brightness light/slow breathing rhythm	Natural sounds or low-volume white noise	Optional low-intensity rhythmic vibration	Provide relaxation cues while allowing active user choice
Relaxation stage	Brightness gradually decreases	Volume gradually decreases	Brief, low-intensity, intermittent	Reduce continuous stimulation and progressively reduce channel use
After expected sleep onset	Off	Off or at a user-set, very low volume	Off	Avoid continuous disturbance after sleep onset

4.3. Product modules and form implementation

The concept includes four modules. The visual module provides low-brightness indirect light, rhythmic guidance, gradual dimming, and shutoff. The auditory module delivers adjustable natural sounds, white noise, or other auxiliary content through low-interference output. The tactile module provides optional, brief, low-intensity vibration through the rear temples. A control module supports one-button activation, intensity adjustment, and timed shutoff, reducing pre-sleep phone use.

The form uses a lightweight frame, flexible contact structures, and thin temples. Pressure at the temples and behind the ears should be minimized, especially during side sleeping. The proposed scheme remains a user-needs-derived concept. Functional parameters, comfort, safety, optical output, and acoustic performance require prototype validation.

5. Discussion

The central result is not that users want more channels, but that they want control across contexts and over time. Although the three-modality option had the highest selection rate (29.1%), simultaneous activation scored only 3.34, whereas stage-based reduction scored 4.17. Sleep-aid multimodality should therefore coordinate roles and exits: visual cues support pre-sleep relaxation, auditory feedback provides relaxation and noise masking, and tactile feedback remains optional. This interpretation accords with multimodal interaction research emphasizing channel coordination [13–15].

The evidence-principle-strategy framework links survey findings with design decisions. Dormitory and travel disturbances informed context presets, attenuation preferences supported timed feedback reduction, and comfort requirements guided structural optimization. These findings provide testable directions for prototype evaluation.

This study has four limitations. The non-probability sample limits generalizability. The questionnaire explored user needs rather than clinical sleep assessment. Prototype parameters, including comfort, optical, acoustic, and vibration performance, require further validation. The absence of objective sleep measures and controlled experiments prevents causal claims. Future studies should evaluate prototypes through usability testing and validate outcomes using PSQI, ISI, or objective sleep indicators.

6. Conclusion

Using 182 valid questionnaires, this study identified context-specific disturbances and preferences for visual, auditory, and tactile feedback among users aged 18–35. Automatic shutoff, adjustable intensity, context adaptation, progressive attenuation, and wearing comfort emerged as central requirements. The study translated these findings into an evidence-traceable pathway from sleep scenarios and user needs to design principles, multimodal strategies, and product modules. The framework supports concept development and prototype testing for sleep-aid wearables but does not establish objective sleep improvement.

Disclosure statement

The authors declare no conflict of interest.

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