Vibro-Tactile Parameters	Notes	Implications/Thoughts	For Testing	Self Test	(Test Notes)
Overall	Make tactile messages self-explaining (Van Erp, "Guidelines" 2.2), Vibration vs. pressure? (Schwalk, "Effects")	In the HapticHead experiment, users responded overwhelmingly positively to vibrotactile feedback and found it more helpful for finding virtual objects than auditory feedback. They got used to it and found it comfortable for regular usage, but had mixed opinions on whether or not feedback was loud (Kaul, "HapticHead" Figure 10), in Head-Mounted maze experiment, vibro-tactile feedback had significantly lower route deviation (Kerdegari, "Head-Mounted" Conclusion)	Comfortable stimuli range 15-20 db above absolute threshold (Van Erp, "Guidelines" 2.3)		(HIGH = on max, LOW = off)
Location of Displays	Higher thresholds on hairy skin (Van Erp, "Guidelines" 2.1), only certain body parts have enough spatial acuity for high density (Van Erp, "Guidelines" 2.2), apparent location = perception of single stimulus when two stimuli activated simultaneously at different locations (Van Erp, "Guidelines" 2.4), purpose of displays affects appropriate location of displays (Saket, "Designing")	Apparent location could be used to increase amount of stimulus sites without increating amount of displays; area around head produced >97% success rate in HapticHead experiment, but none used near ear openings (Kaul, "HapticHead")	Thickness of user's hair can weaken stimulus (Kaul, "HapticHead" Experiment 3)		(Research/test on hairier skin areas that come in contact with glasses? Avoid head hair itself)
Magnitude	Subjective magnitude = non-linear function of amplitude (Van Erp, "Guidelines" 2.2)	*Apparent location* is in between the two stimulus locations and depends on relative magnitude (Kaul, "HapticHead")	Can test by using different intensity levels but limited: 1. enlarge intensity near threshold, 2. enlarge area of stimulation (Van Erp, "Guidelines" 2.2), amplitudes above 0.6-0.8 result in pain (Van Erp, "Guidelines" 2.3)		
Spatial Distribution	Lower threshold when there is fixed surround (Van Erp, "Guidelines" 2.1)	Skin often integrates stimuli, meaning perceptions might differ from sum of original stimuli - it is important to avoid spatial masking especially when using pattern recognition (Van Erp, "Guidelines" 2.4)	Use stimuli with different frequencies, one <80 Hz and one >100 Hz to prevent spatial masking (Van Erp, "Guidelines" 2.4)		
Quality/Smoothness	Sine waveform is smoothest, triangle is in between (Van Erp, "Guidelines" 2.1), Testing smoothness by asking users whether it felt like there were multiple distinct events in different places [choppy] or if it seemed to be one event [smooth] (Cholewiak, "Generation" Methods)	In Cholewiak's test, quality emcompasses *smoothness, length, regularity, and straightness* (Cholewiak, "Generation" Figure 3) - each quality is accessed separately with users to minimize variability in definition; make sure to define each quality thoroughly and understandably as quality is subjective	Smoother sensation when vibration is in upward direction (Cholewiak, "Generation" Results)		(Smoothness + comfort vs. choppy + urgency?)
Vibration Pattern/Type	Sine waveform usually used for vibration input (Van Erp, "Guidelines" 2.1), number of vibration patterns and levels of urgency people can distinguish is 4-5 and they can distinguish even without an audio alert (Saket, "Designing"); users can be trained to recognize patterns (Cholewiak, "Vibrotactile Pattern Recognition")	Poorest change detection performance occurs when there are gaps between two vibrotactile patterns and best performance comes when there is no gap between alternating patterns (Gallace, "Failure" Discussion)	Temporal sensitivity of skin is high, so when using single display, time between signals must be >=10 mx (Van Erp, "Guidelines" 2.2), construct patterns with more than one contactor and with pattern cells randomly but evenly distributed to avoid symmetry (Cholewiak, "Vibrotactile Pattern Discrimination")		

Patterns of Displays	Defined as having different vibration patterns across different vibration motors; up to 30% errors in detecting change in sequentially presented patterns (Gallace, "Failure" Discussion)	Many of the vibro-tactile parameters can be mixed/matched and altered between multiple motors to create distinct patterns, would need to focus on specific patterns because risk of *tactile clutter* (perception may be altered/reduced understanding/sensory overload)	Actuator density is important in design of multiple displays, check acceptable acuity of bodily location (Van Erp, "Guidelines" 2.2)	x	(Tried having two motors run simultaneously with varying gap lengths and intensities)
Amount of Displays	Displays should be unobstrusive/comfortable (Van Erp, "Guidelines" 2.3)	Avoid annoying user (Van Erp, "Guidelines" 2.3)	*Apparent location* can be used to minimize amount of displays for maximum stimulus sites (Van Erp, "Guidelines" 2.3)	x	(Used two vibration motors, seems reasonable for glasses - test prototypes with more/less?)
Duration	Threshold decreases when stimulus duration increases, only works for frequences above 60 Hz (Van Erp, "Guidelines" 2.1), vibration motors generate heat and can cause pain over time (Van Erp, "Guidelines" 2.3)	Ensure comfort over long periods of time (Van Erp, "Guidelines" 2.3), how short/long is needed for sole purpose of arousing attention?	Pattern duration effects level of performance, in the pattern recognition test the 52 ms pattern pairs have better performance than the 4 ms, with 1.8% mean increase in the finger and 3.7% in the thigh (Cholewiak, "Vibrotactile Pattern Recognition")		(What is the ideal duration for the vibration stimuli?)
Gap Length	Pulse rate corresponded to perception of urgency level, and vibrotactile was more successful than visual and auditory in this driving test (Baldwin, "Multimodal" Results)	Two stimuli close in time may change perception of magnitude, enhancement occurs when stimuli are separated by 100-500 ms (Van Erp, "Guidelines" 2.4)	Temporal enhancement only happens when stimuli are in same frequency band (Van Erp, "Guidelines" 2.4)	x	(Trying out various delay times on the vibration motors)
Frequency	Lowest threshold with vibration frequencies between 200-250 Hz (Van Erp, "Guidelines" 2.1), most critical frequencies are ~12 Hz, critical range from 1-5 m/s^2 (Van Erp, "Guidelines" 2.3)	Human hairy skin depends on superficial receptors for low frequencies and deep receptors for high frequencies, human vibrotactile range is ~5-1,000 Hz (Mahns, "Vibrotactile Frequency"), in other words bone vibration for higher frequencies and skin-level for below ~80 Hz	No more than 9 lvls of frequency should be used in coding and difference between lvls should be >20% (Van Erp, "Guidelines" 2.2)		(What is the ideal frequency? What about changing frequencies?)
Stimulus Intensity	Square waveform is most intense, there is lot of variation in individual sensation/pain thresholds and also degrades with age (Van Erp, "Guidelines" 2.1)	Individual user should be allowed to adjust stimulus intensity, or else an average minimum intensity used (for the purpose of simply arousing attention)	Use no more than 4 different lvls between the comfort/pain threshold (Van Erp, "Guidelines" 2.2)	x	(Coded a vibration motor to have decreasing intensity; how does changing intensity affect user perception?)

Auditory Parameters	Notes	Implications/Thoughts	For Testing	Self Test	(Test Notes)	
Overall	Auditory is benefitial if: message is simple/short, not referenced later, deals with events in time, calls for immediate action, visual cues unrealistic, and/or user has a lot of movement	In Head-Mounted maze experiment, vibro-tactile feedback was pitted against speech dictated intructions, and interestingly vibro-tactile had lower workload and faster completion/lower travel distance, may have potential with visually impaired people and modality (Kerdegari, "Head-Mounted" Conclusion)	It is possible to either use existing "ear-cons" or design your own, "ear-cons" aka metaphoric sounds are more successful and efficient than speech dictation; music is easy to recognize but also dependent on users' musical background if using for complex cues			
Type	Defined as what type of sound - "beeping" alarm, speech dictation, etc., speech is slow, "earcon" = symbolic sound, divided into three classes: representational, abstract, and semi-abstract (Gärdenfors, "Auditory Interfaces")	If speech is used, consider the environment - voice/vocab/use polysyllabic words; better to use tones but beware false alarms (Ghirardelli, "Auditory-Visual Interactions")	Importance of correspondence between acoustic characteristics of alarm and properties of the message, for example mimicking a heartbeat to monitor heart function (Guillaume, "Judging" Underlying Perceptual Processes)			
Frequency	Pitch of stimulus, tested with no silence between pulses (Baldwin, "Multimodal"), the higher the pitch the greater the perceived urgency (Guillaume, "Judging"); it is difficult to distinguish the fundamental frequency of extremely high and low pitches (Ghirardelli, "Auditory-Visual Interactions 5.2)	Pitch is not always applicable because only sounds with regular periodicity for at least a certain duration will be heard as a pitch, and mapping information with pitches only works with users who have a musical background (Gärdenfors, "Auditory Interfaces" 4.1)	In Baldwin's experiment, frequency was tested with no silence between pulses and instead a 20 ms on/offset (Baldwin, "Multimodal" General Methods)		(Age will play a role here, as individual detection range diminishes over time - keep this in mind for pitch range testing, perhaps cater experiments towards target ages)	
Stimulus Intensity	Intensity is significant in urgency estimation but tricky: louder = greater urgency, but alarms are usually used in high background noise so the potential range is limited; too low = won't be heard, too high = painful/annoying (Guillaume, "Judging")	If intensity is a main factor, control it systematically (Guillaume, "Judging")	Recommended that intensity level be between 15 db - 25 db above masked threshold (Guillaume, "Judging")			
Rate (Tempo)	Rate or tempo is expressed as duration between onset of successive tones (interonset interval, ms) and inversely related to musical concept of tempo as beats/min (Guillaume, "Judging")	The faster the rate, the greater the perceived urgency (Guillaume, "Judging"), unpredictable temporal events are more attention-getting and enhance degree of urgency (Guillaume, "Judging" Underlying Perceptual Processes)	Temporal structure of alarms should have silent periods that allow time to plan action/communicate (Guillaume, "Judging")			
Duration	Pulse-to-pulse duration defined as duration from start of one pulse to start of next pulse (Baldwin, "Multimodal" General Methods)	Baldwin's test used standardized 2500 ms total duration for auditory stimuli (Baldwin, "Multimodal"), what is the minimum total duration for arousing attention?	Pulse rate derived with this formula: *2500ms/pulse-to-pulse time* (Baldwin, "Multimodal" General Methods)		(Total duration vs pulse-to-pulse duration, which is more significant?)	
Timbre	Timbre as a function of overtone structure, harmonic content, envelope, transient attack, etc., recognizable without references (Gärdenfors, "Auditory Interfaces" 4.1)	In Guillaume's experiments, timbre was one of the particularly important acoustic characteristics for establishing urgency (Guillaume, "Judging"), timbre is hard to describe/notate precisely but is immediately recognizable among auditory parameters (Ghirardelli, "Auditory-Visual Interactions)	Tone timbre should avoid spectral overlap (Guillaume, "Judging")		(Which timbres are best for arousing attention? Is simply using the recognizable timbre of an alarm clock enough?)	
On/Offset Ramp	Fast onset and offset ramps were perceived as the most urgent (Guillaume, "Judging" Experiment 1 Discussion)	There are possibilities that extend beyond the onset/offset ramps of individual sounds, and mixing and linking ramps can create rhythmic patterns and melodies with complex meanings (Gärdenfors, "Auditory Interfaces" 4.2)	Modulating the amplitude of a sound creates roughness/fluctuation strength, or amplitude modulation between 15 and 300 Hz, and is greatest at modulation rate of 70 Hz (Ghirardelli, "Auditory-Visual Interactions")			
Harmonic Regularity	The more irregular the harmonics, the greater the perceived urgency (Guillaume, "Judging")	Low pitch progressively falling over time was the type of harmony that had least urgency (Guillaume, "Judging" Experiment 1 Discussion)	Add dissonance, or lack of harmonicity, to increase urgency			

Rhythm	Listeners respond more to rhythm than other musical parameters; rhythm = timing/weighting of notes (Ghirardelli, "Auditory-visual Interactions" 5.1)	In Brewster's experiments, earcons were designed with changes in timbre/spatial/rhythm mapped to different lvls/positions in a menu hierarchy - there was 80% success (Gärdenfors, "Auditory Interfaces 4.2)	Performance doesn't necessarily improve with redundance (Ghirardelli, "Auditory-Visual Interactions")			
Spatial	Spatial audio rendering can make recorded sounds appear to come from other locations in relation to the user (Heller, "Where Are We?" Introduction)	Smartphones/sensors have the capability to run high-fidelity spatial audio rendering algorithms (Heller, "Where Are We?" Abstract), spatial localization tuned to a user's individual anatomy allows for spatial manipulation (Heller, "Where Are We?" Introduction), some users may have trouble with spatial recognition	Use audio filters to make sources seem fixed at certain positions in physical world (Heller, "Where Are We? Introduction)		(In Heller's experiments, there wasn't a significant difference between recognizing sounds in different spatial locations - would spatial distribution matter for arousing attention?)	