Signaling Desaturation with Enhanced Pulse Oximetry Tones

Appendix 1

Sanderson et al.

Appendix 1. Summary of studies enhancing the variable-tone pulse oximetry sonification, performed at The University of Queensland. For the display conditions with acoustic enhancements, the enhancements were added to the tone, or the tone was changed, when SpO_2 was outside the target range. For adult SpO_2, warning is equivalent to low and crisis to very low.

Study	Clinical population(s) and scenarios	Study participants	SpO_2 ranges, with associated saturation percentages	Auditory displays + enhancements when SpO_2 outside target range	Timeshared task(s) and ambient sounds
Hinckfuss et al. (2016)	Neonatal Multiple 20-s scenarios	Non-clinicians	Very high (100–99) High (98–96) Target (95–90) Low (89–84) Very Low (83–80)	3 displays compared: - **Loglinear** (200 ms, 2.62%) - **Loglinear but different pitch step %** - **Loglinear + beacon** (q 4)	None
Deschamps et al. (2016)	Neonatal Multiple 30-s scenarios	Non-clinicians	Very high (100–99) High (98–96) Target (95–90) Low (89–84) Very Low (83–80)	3 displays compared: - **Loglinear** (200 ms, 2.75%) - **Loglinear + tremolo** (3 vs. 6 cycles) - **Loglinear + beacon** (q 4)	None
Hinckfuss (2018)	Neonatal Multiple 30-s scenarios	Non-clinicians, Clinicians	Very high (100–99) High (98–96) Target (95–90) Low (89–84) Very Low (83–80)	3 displays compared: - **Loglinear** (150 ms, 1.86%) **+ alarm** (Critical) - **Loglinear + tremolo** (3 vs. 7 cycles) - **Loglinear + beacon** (q 8, q 4)	Forced-pace arithmetic verification task Recorded background hospital noise

Study	Clinical population(s) and scenarios	Study participants	SpO_2 ranges, with associated saturation percentages	Auditory displays + enhancements when SpO_2 outside target range	Timeshared task(s) and ambient sounds
Zestic et al. (2019)	Neonatal Multiple 30-s scenarios	Non-clinicians	Varying ranges per mins since birth: High, Target, Low	3 displays compared: - **Loglinear** (150 ms, 1.86%) - **Loglinear + tremolo** (3 vs. 5 cycles) - **Loglinear + tremolo + brightness** (3 harmonics High)	Forced-pace arithmetic verification task
Clarke (2021)	Neonatal Multiple 30-s scenarios	Non-clinicians	Varying ranges per mins since birth: High, Target, Low	4 displays compared: - **Loglinear** (300, 200, 150 ms, 1.02%) - **Loglinear + SpO_2 formants** ('oh', 'ah', 'ee') - **Loglinear + HR tremolo** (2 cycles Low, 4 cycles High) - **Loglinear + both the above**	Forced-pace arithmetic verification task
Paterson et al. (2016)	Pediatric/Adult Multiple 30-s scenarios	Non-clinicians	Target (100–97) Warning (96–90) Critical (89–80)	2 displays compared: - **Loglinear** (200 ms, 2.62%) - **Loglinear + tremolo** (4 cycles) **+ brightness** (4 harmonics Critical)	None
Paterson et al. (2017)	Pediatric/Adult Multiple 60-s scenarios	Non-clinicians	Target (100–97) Warning (96–90) Critical (89–80)	5 displays compared: - **Alarm only** (Critical) - **Loglinear** (150 ms, 1.84%) - **Loglinear + alarm** (Critical) - **Loglinear + tremolo** (4 cycles) + **brightness** (3 harmonics Critical) - **Loglinear + tremolo + brightness + chirp**[1]	Forced-pace arithmetic verification task Recorded background OR noise Pop music with vocals

Study	Clinical population(s) and scenarios	Study participants	SpO_2 ranges, with associated saturation percentages	Auditory displays + enhancements when SpO_2 outside target range	Timeshared task(s) and ambient sounds
Paterson et al. (2019)	Pediatric/Adult Multiple 60-s scenarios	Non-clinicians, Clinicians	Target (100–97) Warning (96–90) Critical (89–80)	2 displays compared: - **Loglinear** (150 ms, 1.84%) **+ alarm** (Critical) - **Loglinear + tremolo** (4 cycles) **+ brightness** (3 harmonics Critical)	Forced-pace arithmetic verification task Keyword detection task Recorded background OR noise Pop music with vocals
Paterson et al. (2020)	Pediatric/Adult Two 20-min scenarios	Clinicians	Target (100–97) Warning (96–90) Critical (89–80)	2 displays compared: - **Loglinear** (150 ms, 1.84%) **+ alarm** (Critical) - **Loglinear + tremolo** (4 cycles) **+ brightness** (3 harmonics Critical)	Patient categorisation task Background simulator chatter Pop music with vocals
Collett et al. (2020)	Pediatric/Adult Multiple 60-s scenarios	Non-clinicians	Target (100–97) Warning (96–90) Critical (89–80)	2 displays compared: - **Discrete effects =** Loglinear (150 ms, 1.86%) + tremolo (5 cycles Low, 8 cycles Critical) + brightness (2 harmonics Critical) - **Incremental effects =** Loglinear + tremolo + brightness (but gradual changes in enhancements within SpO_2 ranges)	Forced-pace arithmetic verification task Recorded background OR noise Pop music with vocals

[1] In the target range, a chirp sound replaced the variable-pitch pulse oximetry tone, sounding every 5 seconds.