

- In Industry 4.0, the factory worker will still maintain a key role [1].
- Wearable devices play an important role in connecting the worker with production processes, for instance by sending notifications [2].
- Special conditions in factories (e.g. noise) might obstruct the information flow.
- Wrist-worn wearable devices, like smartwatches, enable location-independent visual, acoustic, and vibro-tactile notifications [3].

How should notifications be designed to be easily detected by the worker in an industrial environment [5]?

- H1: Response times: vibro-tactile < acoustic < visual
Usability: vibro-tactile > acoustic > visual
- H2: Response times: 1 modality > 2 modalities > 3 modalities
Usability: 1 modality < 2 modalities < 3 modalities

METHOD

- Laboratory experiment with 38 participants (22 female, 15 male, 1 other), within-subject design
- Mean age: $M = 23.26$ years ($SD = 6.30$ years)
- Main task: block building
- Second task: "Think-aloud" and mention the detection of a notification
- Industrial noise (70 dB)
- Response times retrieved from video recordings & usability rating via questionnaire (System Usability Scale [4])

Table 1. Experimental conditions.

Combination of modalities	Modality of notifications		
	acoustic	vibro-tactile	visual
	acoustic & vibro-tactile	acoustic & visual	visual & vibro-tactile
	acoustic & vibro-tactile & visual		



Figure 1. Smartwatch with visual notification.

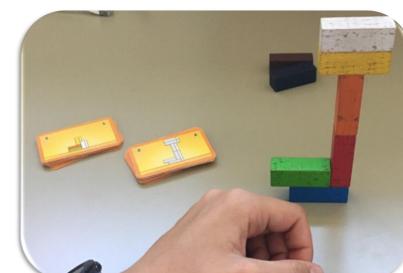


Figure 2. Main task: block building (Make 'n' Break).

RESULTS

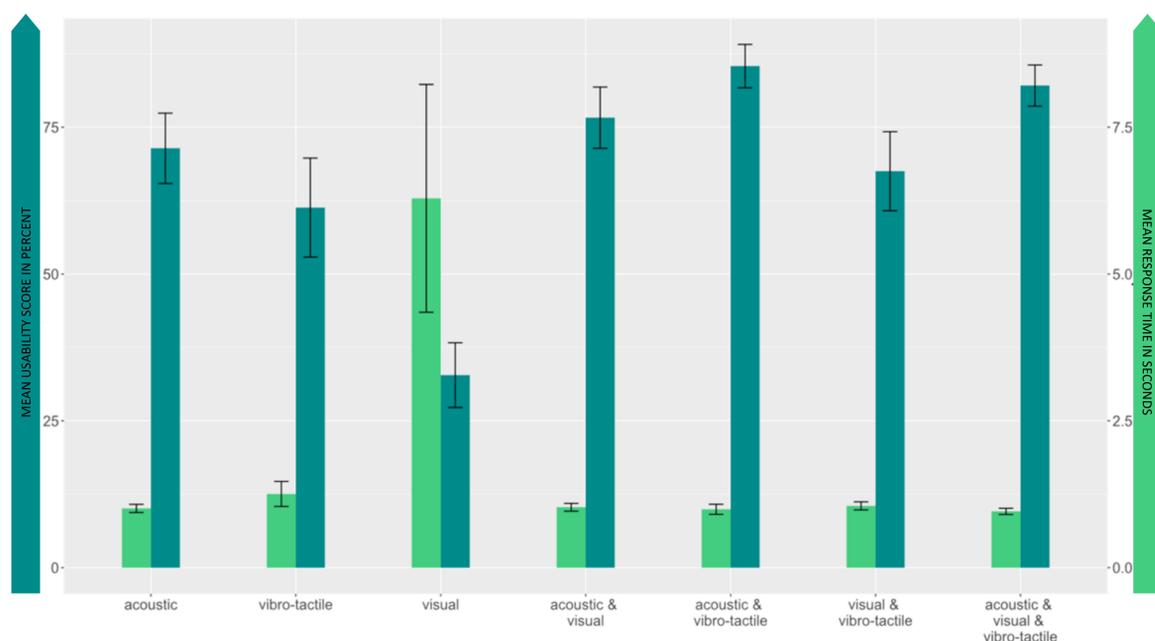
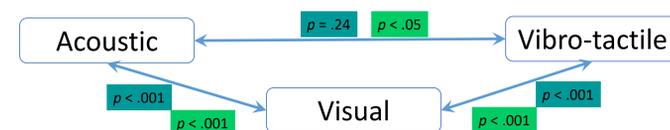


Figure 3. Mean response time and mean usability rating for notification modalities and combination of modalities with 95% CI.

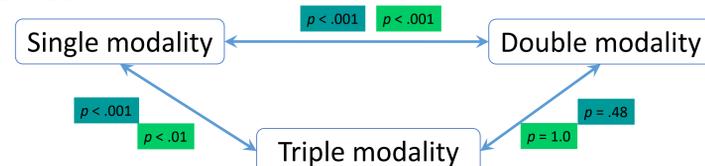
- H1: Significant main effect of modality for **response time** ($F(2,38) = 25.69, p < .001, \eta^2 = .47$) and for **usability rating** ($F(2,74) = 34.38, p < .001, \eta^2 = .39$)

Post-hoc:



- H2: Significant main effect of combination of modalities for **response time** ($F(2,36) = 28.711, p < .001, \eta^2 = .51$) and for **usability rating** ($F(2,74) = 102.11, p < .001, \eta^2 = .55$)

Post-hoc:



DISCUSSION

- In an industrial environment, participants preferred acoustic and vibro-tactile modality of notifications over visual.
- Best response time was achieved via acoustic notification (besides industrial noise of 70 dB).
- A combination of modalities is most suitable in respect of response time and usability.
- In conclusion, important notifications via wearable devices in an industrial environment should use a combination of modalities including acoustic and vibro-tactile modalities.

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