Scaling Notifications Beyond Alerts: From Subtly Drawing Attention up to Forcing the User to Take Action

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ABSTRACT
Research has been done in sophisticated notifications, still, devices today mainly stick to a binary level of information, while they are either attention drawing or silent. We propose scalable notifications, which adjust the intensity level reaching from subtle to obtrusive and even going beyond that level while forcing the user to take action. To illustrate the technical feasibility and validity of this concept, we developed three prototypes. The prototypes provided mechano-pressure, thermal, and electrical feedback, which were evaluated in different lab studies. Our first prototype provides subtle poking through to high and frequent pressure on the user's spine, which significantly improves back posture. In a second scenario, the user is able to perceive the overuse of a drill by an increased temperature on the palm of a hand until the heat is intolerable, forcing the user to eventually put down the tool. The last application comprises of a speed control in a driving simulation, while electric muscle stimulation on the users' legs, conveys information on changing the car's speed by a perceived tingling until the system forces the foot to move involuntarily. In conclusion, all studies' findings support the feasibility of our concept of a scalable notification system, including the system forcing an intervention.

Author Keywords
Scaling notifications; electrical muscle stimulation; thermal feedback; haptic feedback; wearable prototyping.

CCS Concepts
• **Human-centered computing~Interaction techniques**

INTRODUCTION
Notifying the user of incoming messages, calls, activity goals, calendar events, alarms, etc. [17] are common scenarios nowadays. Also, using our haptic sensory channel [7] to draw the user's attention, has been demonstrated extensively. Nevertheless, notifications can quickly annoy the user with irrelevant content, create unwanted task interruptions, or even overlooked [16]. Therefore, we need to ask the question: *How can we convey information appropriately to the context to the user and how can we possibly intervene in an interaction scenario?*

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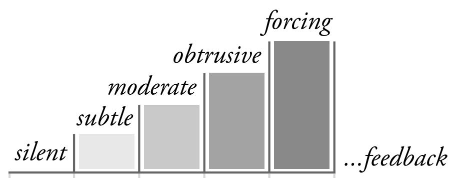
In this paper, we outline a possible answer by introducing the concept of *Scaling notifications beyond alerts* – a scalable notification system that, on the one hand, provides very subtle feedback to the user while, on the other hand, can intervene and force the user to act. While subtle notifications may be quickly overlooked or intentionally ignored without great effort and disruption, these types of notification are only suitable for less important information. However, there may be very urgent notifications, such as important information concerning our health. These notifications should be transmitted at a level beyond being obtrusive, where it cannot be overlooked and possibly forces the user to act.



	silent	subtle	moderate	obtrusive	forcing
pressure force (Nm)	0	0.3	0.9	1.5	1.8
frequency (Hz)	0	2	2.5	3.3	5
thermal temperature (°C)	24	30	35	43	68
electrical current (mA)	0	10	12	20	22

Figure 1. We developed 3 prototypes providing mechano-pressure, thermal, and electrical feedback and tested to distinguish 5 stages of notifications. The table provides all important parameters to enable replicability of our feedback. ***Please note:*** **Parameters for electrical feedback are user-dependent and need to be set individually.**

Similar approaches can be found in literature, which is demonstrated in *Tactful Calling* [10]. Depending on the caller's input, the person being called receives either a subtle or rather obtrusive call notification (silent/blinking, vibrating, or a loud audio notification). Another related work demonstrates audio text messages in *Nomadic Radio* [18], in which seven increasing levels of audio feedback (silence, ambient cues, auditory cues, message summary, preview, full body, and foreground rendering) are conveyed via a wearable speaker worn around the neck. Scaling haptic notifications, in particular to a forcing level, has not been demonstrated yet.

With the idea of *forcing feedback*, we extend it further than simply creating a force to resist. Instead, the user's body parts are forced to move in a specific way or direction. This is demonstrated with electric muscle stimulation (EMS), which Lopes et al. [13] presents, by forcing body parts to move, such as hand movements driven by the computer. Hassan et al. [9] also applied EMS to the calf muscles to force a different foot posture. *Forcing feedback* can also be implemented using a mechano stimulus, such as by pulling earrings [11], force-dragging shoes [8], and strangulating sleeves [5]. Triggering reflexes is another way of forcing the user to take action, which Kon et al. [12] demonstrates, by making the head and the body turn. Forcing the user's eyes to blink through light flashes, physical taps, and small puffs of air has also been demonstrated [6] to trigger reflexes.

EXAMPLE APPLICATIONS

We aim to extend previous research while combining scalable notifications with *forcing feedback* by mechano-pressure, thermal, and electrical feedback. To underline our concept, we developed three prototypes that demonstrate the feasibility in three different scenarios: (1) body posture correction, (2) hand-arm-vibration (HAV) overuse prevention, (3) car speed control, in which we apply several nuances of tactile notifications, which are; not. 1: *silent feedback*, not. 2: *subtle feedback*, not. 3: *moderate feedback*, not. 4: *obtrusive feedback*, and not. 5: *forcing feedback* (*Figure 1*). We evaluated three independent scenarios, to illustrate the broad applicability of our proposed concept.

Body Posture Correction (Mech.-Pressure)

Poor back posture can lead to spinal musculoskeletal disorders, such as bone spurs and intervertebral disc damage [1]. Making users continuously aware of a poor posture significantly reduces out-of-posture tendencies and encourages healthy spinal habits [20]. Awareness can be created by triggering events of discomfort, which the user attempts to avoid [19]. We developed a haptuator device (*Figure 2*) - a back piece that is mounted on the area of the thoracic vertebrae, which is the middle-upper part of the spine. We used a powerful 12V servo-motor providing torque of approx. 160oz-in. The force is translated via a horizontal gear into a linear force that slides the metal bar from two 5V Solenoid haptuator coils (ZHO-0420L) towards the back. There, two metal rods push themselves just next to the vertebrate, the corpus of the spine.

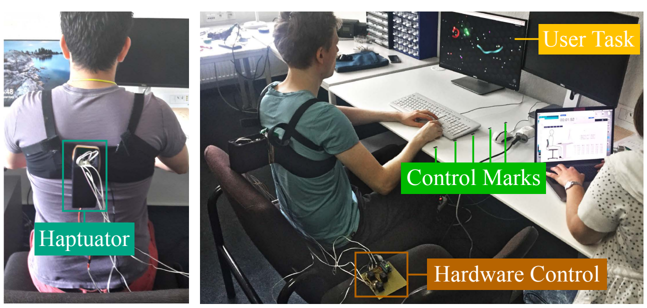


Figure 2. The haptuator is tightly mounted to the user's back using velcro tape. The user is playing Slither.io, while the study leader triggers random notifications. The back's degree-angle, calculated from an accelerometer, is being constantly logged. Also, 5 different keyboard distances were tested.

We invited 13 subjects (*M*=25yrs; *SD*=4.08yrs) and perceived an average drift into a bad sitting posture of *M*=2.04° (*SD*=0.8°) within the first 2 minutes, while the users were occupied with a primary task. While notifications 2-4 could already slightly correct posture, notification 5 was triggering a reflex when pressing the rods next to the spine, which forced the user to sit upright again.

HAV Overdose Prevention (Thermal)

Many tools used by handcrafters and heavy workers create considerable hand-arm vibrations (HAV), which can cause irreparable damage to the sensorineural [2] and muscular [3] system. Regulations [4] are supposed to protect the workers, which obliges the employer to evaluate HAV and comply with the limit of the daily dosage of A(8) = 5 m/s^2. Although, we can track HAV by unmodified smartwatches [14], appropriate notifications are missing. Moreover, workers tend to ignore such notifications, even when the daily dose is exceeded. Providing implicit feedback on the user's palm using heat can be a visualization which does not disturb the user's primary task, while simultaneously scaling up the feedback to a level that cannot be ignored.

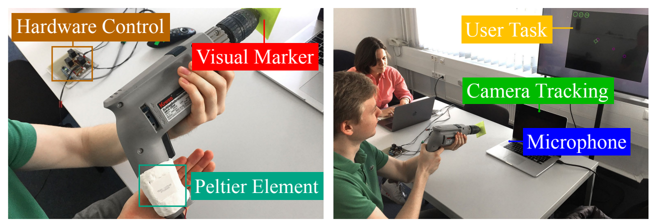


Figure 3. A peltier element (TES1-127025) is attached to the handle of a drill. In a lab environment, the subject had to aim at moving circles displayed at a 50" screen and drill them into thin air. The position tracking is done with an RGB webcam and drilling is detected by the microphone.

We designed a lab study (*Figure 3*) to evaluate the perception of thermal notifications, which involved in a drilling task and invited 15 study subjects (*M*=25.5yrs; *SD*=3.11yrs). Although notifications 2-4 were clearly distinguishable from notification 1 and 5, not. 2-4 were ambiguous among themselves and prone to confusion. Not. 1-4 did not have a significant impact on task performance. Not. 5 triggered a task interruption, since the user had to place the drill down, because the high heat created too much discomfort.

Car Speed Control (Electrical)

Notifications can be particularly beneficial in critical scenarios when attention is deviated from the primary task. Driving is such a typical task, which we simulated in a lab study (*Figure 4*). We attached electrodes to the user's calf creating a light tingling up to a pressing sensation using a nerve stimulator (Pierenkemper TNS SM 2 MF). The forcing notification would stimulate the muscle in a way that causes involuntary foot movements including pushing down on the gas pedal. While there are certainly greater methods of controlling the gas pedal, this scenario is purely an example to demonstrate the power of a scaling notification using EMS.

We recruited 15 participants (*M*=25.5yrs; *SD*=3.11yrs) and found notifications 2-5 to help decreasing reaction time, and task completion time at the primary task. Also, *forcing feedback* (not. 5) significantly improved task performance, such as to accelerate.

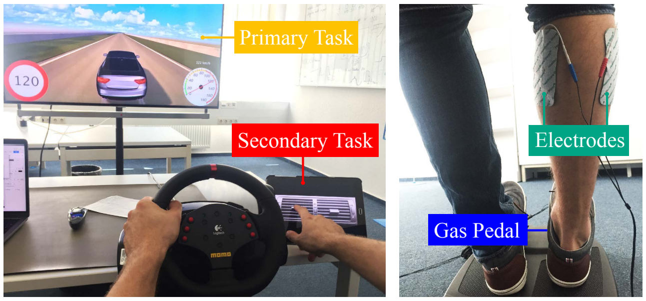


Figure 4. Our driving simulator specifies a certain speed limit, which changes at random but needed to be followed. At the same time, the user's attention is deviated from the primary task, while the user needed to control the airflow, switch music, open the window, etc. at the car's interior displayed on a tablet.

CONCLUSION

We propose *Scaling notifications beyond alerts* and demonstrate the feasibility of scaling a single feedback type until exceeding the threshold of obtrusiveness and thus forcing the user to act. We believe, such intervening notification to provide unique situational benefits, such as to avoid critical events. To illustrate our idea, we conducted three lab studies, although the implementation of those may be a long way from being realistic and practical. A complete data analysis of our studies is published separately [15].

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