Perceptual features of everyday push button sounds and audiotactile interaction

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Abstract: The first aim of this study is to investigate the relationship between the signal properties and the perceptual attributes of everyday push button sounds and the second aim is to investigate the effect of loudness on the perceived tactile feedback intensity from buttons. This knowledge is useful for product designers and sound engineers to find an optimum button sound and haptic feedback for a defined application. In the first step of this study, the physics and signal properties of button sounds are discussed, and an investigation was conducted to determine the users’ common language to describe the perceptual properties of everyday button sounds. The results of this investigation showed that the fundamental perceptual factors of button sounds are pleasantness, confirmation, alerting, irritating, and quality. In the next step, a listening experiment was conducted to investigate the relationship between signal properties, such as frequency and damping, and the perceptual factors above. The second part of this study is concerned with auditory-tactile interaction. An experiment was conducted to understand the effect of button sound on the perceived tactile feedback. The results of the experiment clearly show that in bimodal judgments both haptic and auditory information contribute to the perceived tactile strength.

Keywords: Psychoacoustics, Button sound, Pleasantness, Audiotactile interaction, Haptics

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1. INTRODUCTION

Currently, push buttons are used as operating elements in an array of devices, from household appliances to vehicles. Over time, the number of push button applications and functions has grown significantly. Therefore, optimum adaptation to human activities, apart from simple functionality, is extremely relevant in the development of modern operating elements. In this context, the feedback quality of push buttons is of considerable importance. Main areas of button applications include switching operations, text entry, numerical input, and time continuous processes. If a conventional push button is pressed, audio, tactile and visual feedback confirms successful operation. Furthermore, in various web, smart phone, and touch screen applications, synthesized button sounds are used. The results of recent studies, which measured the task performance or the comfort of use, show that the presence of feedback sounds can substantially improve the quality of such user interfaces [1–3].

This study focuses on perceptual features of button sounds. The aim is to investigate the relationship between perceptual features of button sounds and signal parameters, such as frequency content and damping. The remainder of the paper is organized as follows: the physical generation of button sound and the associated signal characteristics are discussed in Sect. 2. The elicitation investigation to determine verbal descriptors of button sound, and the main perceptual factors are described in Sect. 3. The evaluation experiments of button sounds are discussed in Sects. 4 and 5. Section 4 focuses on the signal properties of frequency and damping. Section 5 investigates how the perceptual attribute ratings of a button sound change when the sound consists of two audible impulses rather than a single impulse. Except of auditory perception alone, the auditory-tactile interaction is also very important for the perception of buttons. Therefore the investigation on the effect of loudness on the perceived tactile feedback was summarized in Sect. 6.

2. CONVENTIONAL AND SYNTHESIZED BUTTON SOUNDS

2.1. Physics and Signal Analysis of Conventional Button Sounds

A conventional button consists of three metal bars (Fig. 1). Two of the bars are stationary, and the third bar is...
moveable and functions like a spring. If the button is pushed, then the moveable bar will make contact with one of the stationary bars, thus closing the circuit and allowing current to flow. As soon the button is released, the moveable bar will return to its previous position. During this movement, the moveable bar vibrates and generates a sound, known as button sound. The push button sound has an impulsive character (Fig. 2). Various resonance frequencies of the bar are excited during the contact phase. The physical parameters of the bars, such as length, height, thickness, stiffness (characterized by Young’s modulus), and material density influence which frequencies are excited. The decay times of these frequencies depend on the damping properties of the material and additional damping, if it was applied.

\[ x(t) = A_1 \cdot e^{-\delta_1 t} \cdot \sin \omega_1 + A_2 \cdot e^{-\delta_2 t} \cdot \sin \omega_2 + \cdots + A_n \cdot e^{-\delta_n t} \cdot \sin \omega_n \]

(1)

In most cases, the vibrations of the bar are also transmitted to the housing of the button. Because of the housing, some additional resonances will be excited. However, sound recordings of vibrations show that this is not always the case.

2.2. Synthesized Button Sounds

Most designed (synthesized) button sounds have time courses that are similar to those of conventional button sounds. Various synthesis methods can be applied to design button sounds [4–9]. The frequencies utilized, and their decay times, evoke various user reactions. From our daily life experiences, we know that some button sounds are well suited to provide confirmation feedback, and other sounds are well suited to alert the user of incorrect input. From the point of view of sound designers or button constructors, an understanding of the relationship between the perceptual features and signal parameters of button sounds is necessary. Although some scientific studies on this subject exist [10–13], a clear set of guidelines and a body of knowledge are missing.

3. INVESTIGATION TO DETERMINE THE PERCEPTUAL ATTRIBUTES OF THE BUTTON SOUND

The first part of this study aims to determine the users’ common language for describing the perceptual properties of button sounds and to identify important perceptual dimensions. Therefore, buttons of various devices, such as a keyboard, mouse, radio, hi-fi equipment, light switch, etc. were selected; altogether, 34 conventional button sounds were recorded binaurally in an anechoic chamber. Additionally, 32 synthesized button sounds from various web, PC software, household appliance, and car audio applications were collected. A total of 66 sound stimuli were used in this investigation. To elicit the verbal descriptors, the multi-sequential systematic approach described in [14], was used. In the training session, users pressed the buttons of the above devices, made text entries using different keyboards, and surfed the Internet using different mice. In the free verbalization interview, participants described the 66 button sounds, which resulted in a list of 632 descriptive attributes.

In the next step, we checked whether all participants understood these attributes and asked them to evaluate the suitability of these attributes to describe perceptible properties of the button sounds (a detailed description of the investigation steps can be found in [14]). After the understanding and suitability checks, the number of attributes was reduced to 38 (Table 1).

Next, a semantic differential investigation was conducted using these attributes, which are listed in Table 1. The sound database consisted of the previously mentioned 66 button sounds. Participants assessed the intensity of their associations (such as pleasant, irritating, etc.) on a
A factor analysis was conducted on the semantic differential data using a varimax rotation. The Kaiser-Meyer-Olkin measure of sampling adequacy yields a result of 0.89. The factor analysis revealed five factors (some of them are combined) that explained 89% of the variance. The first factor was termed pleasant (32%), the second was called quality and confirmatory (23%), the third was called alerting (20%), and the fourth was called irritating (14%). It was observed that there are some relationships between these perceptual factors and signal parameters, such as frequency, loudness, and temporal properties. However, it is not possible to describe these relationships systematically because the signal parameters of the stimuli vary in a complex way. Therefore, it was decided to conduct a further investigation with systematic variations of button sound parameters.

4. EVALUATION EXPERIMENT — SIGNAL PROPERTIES: FREQUENCY AND DAMPING

This part of the study establishes the relationship between the perceptual properties of button sound and the frequency and damping coefficients.

4.1. Stimuli

The stimuli were synthesized at a sampling frequency of 44.1 kHz using exponentially decaying single pure tones, which vary in frequency (100 Hz, 200 Hz, 400 Hz, 800 Hz, 1,200 Hz, 2,000 Hz, 4,000 Hz, 8,000 Hz, 12,000 Hz). The duration of the stimuli was 200 ms and their decay times were varied using two different damping constants, \( \delta_1 = 100 \) and \( \delta_2 = 300 \) (Fig. 3). The decay times were selected due to their clear perceptual differences. A loudness matching experiment conducted with 10 subjects to equalize the perceived loudness level of the stimuli. The method of adjustment was used as psychophysical method. 800 Hz was selected as reference stimulus with sound pressure level of 54 dB(A). The task of the subjects was to adjust the loudness of a test stimuli to the loudness of the reference stimulus using an endless rotary knob.

4.2. Subjects

Thirty people (17 males and 13 females) participated in the experiment. Their ages ranged between 20 and 55 years. All subjects were native German speakers and had normal hearing ability. They were paid on an hourly basis. The subjects had no specific acoustic knowledge or technical background.

4.3. Set-up

The auditory stimuli were presented from a PC. They were amplified and delivered diotically through Sennheiser HD open-face dynamic headphones. To guarantee a problem-free reproduction of the impulsive sounds, an external sound card (M-Audio FastTrack Pro) was used in the experiment. Matlab was the reproduction software. A touch screen (without tactile feedback) was used to activate the button sounds. The experiments were conducted in a sound-attenuated room.

4.4. Procedure

In the training phase, all of the participants were presented with different combinations of stimuli from across the full stimulus range; they were then familiarized with the procedure of the experiment. Participants listened to the button sounds and assessed the intensity of their associations on the quasi-continuous graphical scale, which

\[ \begin{align*}
\delta_1 &= 100 \\
\delta_2 &= 300 
\end{align*} \]

Table 1 The set of button sound attributes.

| Button Sound                          | Aggressive (aggressiv) | Alerting (warnend) | Annoying (lästig) | Appropriate (passend) | Artificial (künstlich) | Beeping (piepsend) | Cheap (billig) | Chiming (schlagend) | Clear (klar) | Confirmatory (bestätigend) | Damped (gedämpft) | Fast (schnell) | Funny (lustig) | Hard “to press” (hart) | High frequency (hochfrequent) | Innovative (innovativ) |
|--------------------------------------|------------------------|--------------------|------------------|-----------------------|------------------------|-------------------|---------------|----------------------|--------------|--------------------------|-------------------|----------------|---------------|------------------------|---------------------------|-------------------|
| Interesting (interessant)           |                        |                    |                  |                       |                        |                   |               | Precise (präzise)     |              | Pleasant (angenehm)       |                   | Simple (simpel)       | Raspy (kratzend)       | Typescript-like (schreibmaschinenartig) | Unique (besonders)       | Unobtrusive (dezent)  |
| Irritating (nervig)                  |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   | Robust (robust)       |                           |                           |                           |
| Annoying (la¨stig)                   |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Known (bekannt)                      |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Loud (laut)                          |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Noble (edel)                         |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Old-fashioned (altmodisch)           |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Overall quality (Gesamtqualität)     |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Precise (präzise)                    |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Clear (klar)                         |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Pleasant (angenehm)                  |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Rickety (klapprig)                   |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Robust (robust)                      |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Simple (simpel)                      |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Raspy (kratzend)                     |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Typescript-like (schreibmaschinenartig) |                    |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| (schreibmaschinenartig)              |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Unique (besonders)                   |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |
| Unobtrusive (dezent)                 |                        |                    |                  |                       |                        |                   |               |                      |              |                          |                   |                           |                           |                           |

Fig. 3 Time course of two damping constants for 100 Hz.
was explained in Sect. 2. The questionnaire contained the perceptual properties, such as pleasant, quality, confirmatory, alerting, and irritating. Stimuli were presented in a random order. A graphical user interface was implemented for the evaluation experiments in Matlab.

4.5. Results

The judgments for the perceptual attributes were averaged across all subjects. The mean scores and the standard deviations are shown in Fig. 4. To better compare the judgments of various attributes with each other, all mean scores are combined. The stimuli were sorted in ascending order according to the frequency, and both damping values were applied successively for each frequency. For the statistical analysis of results, G-Test was used to check the sufficiently normal distribution and one-way ANOVA was used to test the statistical significance.

Fig. 4 The ratings for the attributes of pleasant, confirmatory, quality, irritating, and alerting. The signal properties are frequency and damping.
The results show that very low frequencies, such as 100 Hz or 200 Hz, are not suitable for alerting. However, all frequencies from 400 Hz obtained similarly high alerting ratings, and show no significant differences. Another interesting observation is that lower alerting causes higher alerting ratings than higher damping. This finding is significant for 800 Hz, 1,200 Hz, and 2,000 Hz ($p < 5\%$, in all cases). The same tendency is also observable at other frequencies.

Confirmation feedback is very important in various tasks to allow a good interaction with the user. The scores of the attribute “confirmatory” indicate that middle frequencies, from 400 Hz to 2,000 Hz, are most suitable to provide confirmatory evidence to a user (Fig. 4b). Particularly low and high frequencies were found to be less suitable. There is no evident difference between the two damping conditions. Only at low frequencies, and interestingly at 4 kHz, low damping tends to be better for the confirmation.

The results for the attribute “irritating” show that the higher the frequency, the greater the score. In particular, stimuli from 4 kHz have a very strong irritating effect (Fig. 4c). At low frequencies, there is no evident difference between the two damping conditions. However, from 1.2 kHz, lower damping causes slightly higher irritating scores.

The pleasantness scores are presented in Fig. 4d and show that high frequencies are perceived as less pleasant. From 2 kHz, the higher the frequency, the lower the pleasantness scores. Up to 2 kHz, the stimuli show no significant differences; they were rated almost similarly between very and moderately pleasant. At high frequencies, higher damping was found to be more pleasant than lower damping. Below 2 kHz, damping does not play any significant role.

The overall quality scores are presented in Fig. 4e. The results do not show any clear tendencies, as is the case for the other attributes. The middle frequencies evoke a slightly higher overall quality perception than other frequencies. The highest quality score is slightly higher than moderate. At low frequencies, lower damping causes slightly higher quality ratings. At high frequencies, higher damping causes slightly higher quality ratings.

The sounds associated with a car door closing have an impulsive character and a short time course, similar to button sounds. Studies on the sounds of a car door closing reported that, if the sound consists of two distinctive audible impulses, rather than only one audible impulse, it obtains a higher “confirmatory” and “quality” rating. This knowledge leads to further experiments to examine if the same phenomenon is also valid for button sounds.

4.6. Discussion

The results of the study provide guidelines to define suitable signals for various button-based applications. Depending on the aim of the potential application, it is possible to find the optimum stimulus across the stimulus range.

The results show that if the aim is to find an optimum feedback to evoke a pleasant confirmatory feeling, the stimulus at 1,200 Hz, with damping condition 2, is the most suitable signal across the stimuli. The optimum signal for alerting is the stimulus at 4,000 Hz, with damping condition 1, or the stimulus at 2,000 Hz, with damping condition 1. Lower frequencies are suitable to avoid any nervousness or irritation. It seems that 2,000 Hz is an important threshold for the pleasantness of button sounds.

The results show that high frequencies cause a decrease in the pleasantness of button sound. This observation is in line with other sound quality studies with some impulsive-type sounds, such as car door closing sounds [15,16], knocking sounds from household appliances [17], and sounds of rotary switches [18]. This result is also in line with the research of Fujimoto et al., who studied the perceptual attributes “pleasant,” “metallic,” “force,” and “esthetic” of 11 button sounds [10]. However, some other studies with impulsive-type sounds have indicated that sharp sounds can increase the pleasantness [19]. The study of Roberts et al. showed that a golf shot was rated as having a pleasant feel if it had a sharp sound. This fact indicates that the role of sharpness on the pleasantness can be application dependent.

Particularly in computer applications, but also in some daily life applications, alerting button sounds are used to inform the user about a wrong entry or a wrong interaction. Similar to the various types of alarm signal design studies [20], in some cases, to cause an irritation is not desired and in some cases, it is desired. The results of this study show that, from 400 Hz, all frequencies are similar, with respect to alerting. However, the results indicate that the higher the frequency, the more irritating the sound. This means that it is possible to find optimal alerting button sounds for specific applications.

Various researchers complain about the lack of auditory and tactile confirmation feedback in touch screen applications [1,2,4] or control element applications in cars [21]. The optimal confirmation of the successful operation of a button improves the interaction of the user with the interface or product. Regarding subjective ratings on the attribute “confirmatory,” the middle frequency range seems to be most the suitable for the confirmation. Particularly at high frequencies, the confirmation score decreases rapidly.

Damping variations (low and high) have an influence on the ratings of only three properties. Lower damping
yields higher alerting ratings; there is a similar relationship for the irritating attribute. Conversely, lower damping leads to lower pleasant ratings. However, this evidence is only valid for high frequencies. Sound studies of closing car doors and household appliance knocking also showed that long-lasting high frequency components cause unpleasantness. However, these studies also indicated that long-lasting low frequency components were mostly found to be pleasant. This aspect is not valid for button sounds. Long-lasting, and also short-lasting low frequency components, are judged as similarly pleasant.

The subjective overall quality ratings show very little difference between various frequency and damping conditions. A possible reason for this fact is that it is difficult for the subjects to decide on the overall sound quality without any given completion task. In this study, subjects listened to button sounds and evaluated their perceptual properties. In such a case, it is generally possible to evaluate the pleasantness, or irritating aspects, of the button sound, but the overall quality is much more task-dependent than sound-dependent.

5. EVALUATION EXPERIMENT — SIGNAL PROPERTY: NUMBER OF IMPULSES

5.1. Stimuli, Subjects, Setup, and Procedure

The aim of this experiment is to investigate how the perceptual ratings change if a button sound consists of two successively audible distinctive impulses as opposed to one impulse. Therefore, the stimuli used in the first experiment serve as a starting point for the current experiment. Three stimuli (400 Hz, 800 Hz and 2,000 Hz) with the two damping variations (altogether 6 stimuli) were selected. New stimuli were generated by repeating these 6 stimuli twice, with a pause of 5 ms between them (Fig. 5).

The loudness of the stimuli was equalized subjectively to avoid any influence of the loudness on the judgments. The same subjects from the second experiment participated in this experiment, which had the same procedure as the second experiment. To avoid the subjects knowing that they were directly comparing one impulse with two impulses at the same frequency, the stimuli of the former experiment were mixed with the new stimuli. The presentation order of the stimuli was randomized.

5.2. Results and Discussion

As previously mentioned, the original stimuli of the former experiment were evaluated once more in this experiment to increase the stimuli diversity and to check the consistency of the judgments. The judgments of the subjects were very consistent, with only minor discrepancies. Thus, the ratings of the new stimuli, compared to the single impulse stimuli from the previous experiment, are presented (Fig. 6).

The results show that a repetition of the impulse causes an increase of the confirmatory, alerting, and pleasant ratings. As previously observed using single impulse stimuli, a similar trend in confirmatory rating was also noted for the sounds of a car door closing.

Except for the ratings of the stimulus at 400 Hz d1, the increase in the confirmatory judgments is significant (\( p < 5\% \), in all cases). However, the increase in the ratings is slightly greater for the strong damping condition (d2). This could be due to the duration of the low damping, which is slightly long for a push button process. Two distinct audible impulses over a short duration seem to be more effective to give the user the impression of confirmation. It should be taken into account that in this study, there are only two damping (with respect to duration) variations evaluated. Therefore, it is difficult to estimate the nature of the ratings for very short duration conditions.

The results show that the increase of the alerting rating is the largest amongst the evaluated attributes and is significant in all stimuli cases (\( p < 5\% \)). However, there is not a clear difference between the two damping conditions. In both conditions, the ratings will be higher if the stimuli consist of two impulses rather than a single impulse. Interestingly, similar aspects were also observed in bird communication. Two distinct notes are also used by birds to alert each other; for a greater threat, the number of notes increases [22]. If some physical buttons, e.g., hold buttons in desktop telephones, are engaged, they also generates double “click” sounds as a consequence of their mechanics. Therefore, it is interesting to note that double impulses can improve alerting feedback.

It is possible to recognize a trend in the pleasant ratings, which increases in double impulse cases. However, the results are not significant and the effect is not as strong as in the alerting and the confirmatory evaluations. Very weak trends are also observable for the attributes of quality and irritating.

Fig. 5 An example of a stimulus with two impulses.
6. EXPERIMENT — EFFECT OF BUTTON SOUND ON THE PERCEIVED TACTILE FEEDBACK INTENSITY

6.1. Stimuli, Subjects, Setup, and Procedure

The aim of this experiment is to investigate the influence of the button sound on the perceived tactile feedback intensity. The stimuli used in the first experiment serve as a starting point for the current experiment. Three auditory stimuli (400 Hz, 1,200 Hz and 4,000 Hz) were selected for this experiment. These auditory stimuli were combined with two different tactile signals. The loudness of the stimulus was equalized to the 400 Hz button sound with 50 dB sound pressure level. The duration of the tactile and auditory-tactile signals were 200 ms. The form of the tactile signals were shown in the Fig. 7.

Twenty-five people (18 males and 7 females) participated in the experiment. Their ages ranged between 19 and 25 years old. The experiment was conducted in a quiet laboratory environment to minimize external noise.

![Graphs showing ratings for attributes](image)

Fig. 6  The ratings for the attributes of pleasant, confirmatory, quality, irritating, and alerting. The signal property is the number of impulses.
35 years. All subjects were native German speakers and had normal hearing ability. They did not report any tactile perception problem. They were paid on an hourly basis. The subjects had no specific acoustic and haptic knowledge or technical background.

In this investigation, a touch sensitive system was used that reproduces event triggered tactile or audiotactile feedback. The tactile feedback was generated using an electro-dynamic exciter, which is mounted behind a touch screen. The auditory stimulus was amplified and delivered through Sennheiser HDA 200 closed-face dynamic headphones which have a very high sound isolation level and therefore mask the background noise.

Magnitude estimation was applied as the experimental procedure. Subjects were presented with the variations of unimodal (only tactile feedback information) and multimodal (both auditory and tactile information) feedback. In each evaluation, subjects were asked the perceived tactile feedback intensity by assigning numbers to the test stimuli. Strength magnitude was estimated using a magnitude estimation with an anchor stimuli. In each trial an anchor stimulus was presented and the participant was told that the tactile intensity sensation it produced has a certain numerical value (100). After the anchor stimuli, a test stimulus was presented and the participant’s task was to assign numbers proportional to his/her subjective impression of the perceptual intensity related to the anchor stimuli. Anchor stimulus was an only tactile signal at frequency of 100 Hz. Each trial was presented eight times in a random order. The subjects were specifically instructed to ignore the button sounds they heard, and to base their judgments on only tactile information. In the training phase, all of the participants were presented with different combinations of stimuli from across the full stimulus range; they were then familiarized with the procedure of the experiment.

6.2. Results and Discussion

Figure 8 shows the responses of all subjects. Geometric mean values were computed for the magnitude estimates obtained from all subjects for each stimulus.

Various frequency combinations cause various audiotactile interaction effects. It is obvious that the frequency of button sound play an important role on the button tactile intensity perception. In most cases, both haptic and auditory information contribute to the perceived intensity of the tactile feedback. Button sound causes that the perceived tactile intensity increases. The amount of the increase depends on the frequency of the button sound. Interestingly tactile 10Hz and tactile 20Hz have different interactions with different audio frequencies. Dependent t-tests of the means showed that five conditions differed significantly ($p < 0.05$). The results are line with the studies [23–27]. Guest et al. also noticed that tactile roughness perception was modulated by the frequency content of the auditory feedback [23]. Lee and Spence claim that adding auditory feedback to touchscreen applications might enhance the limited range of tactile feedback [24]. The previous experiences of Brown et al. are confirming this statement [25]. The results of Lee and Spence show that task-irrelevant sounds may modulate people’s perception of the number of tactile stimuli delivered via a touch screen. Possibly the frequency match between auditory and tactile signals can cause other auditory-tactile interaction percepts rather than mismatched frequencies of auditory and tactile signals. The results of this study show that the combination of tactile 10Hz with auditory 1,200Hz causes maximum increase of the perceived tactile feedback intensity. However the combination of tactile 10Hz and auditory 4,000Hz causes lower perceived intensity.

7. CONCLUSIONS

Because of the growing usage of push buttons and their various feedback functions, including flat-panel touch screens, the targeted use and design of the button sound is increasingly important. The results of this study give a fundamental overview on the influence of frequency, damping, and time course on the perceptual attributes of button sound. The results of the audiotactile interaction experiment show that humans do not exactly feel what the
haptic sense tells them, but, rather they integrate the two modalities of hearing and touch.

This work can support sound engineers in the definition of an optimum sound for a defined task. However, the number of the parameter variations was limited in this study. Further investigation of the influence of the combination of different frequencies, further damping conditions, and their interactions on the perceptual attributes, can be investigated.

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