# User Preferences for Calming Affective Haptic Stimuli in Social Settings

Shaun Alexander Macdonald
Euan Freeman
Stephen Brewster
shaun.macdonald@glasgow.ac.uk
euan.freeman@glasgow.ac.uk
stephen.brewster@glasgow.ac.uk
School of Computing Science
University of Glasgow, Scotland

Frank Pollick
frank.pollick@glasgow.ac.uk
School of Psychology
University of Glasgow, Scotland

## ABSTRACT

This paper presents a survey informing a user-first approach to designing calming affective haptic stimuli by eliciting user preferences in different social scenarios. Prior affective haptics research presented users with stimuli and recorded emotional responses. By contrast this work focuses on the sensations users wish to experience and how these can be simulated using haptics. The survey (n=81) investigated which users preferences in four social situations to reduce social anxiety. Using thematic analysis of responses we created a coding scheme of stimuli derived from real-world experiences to emulate with affective haptics. By cross-referencing these categories with affective haptics research, we provide recommendations to designers about which calming stimuli users wish to experience socially and how they can be implemented.

## CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *Haptic devices*; User studies.

## KEYWORDS

Affective Haptics; Personalisation; Emotion Regulation;

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## 1 INTRODUCTION

Affective haptic displays can provide a positive and relaxing intervention to people in social situations without drawing increased scrutiny or stigma, since haptic sensations are discreet [52, 55]. Research has demonstrated that affective haptics can be calming in social situations by giving an external stimuli for users to focus on [4, 54, 58], distracting them from anxious thoughts. Affective haptics have been studied in many forms, e.g., abstract vibration patterns [59], haptics for social robots [10, 58], and mediated touch experiences using a range of haptic devices [26, 44]. All have shown the haptic modality to be a powerful and compelling way of evoking affective response, with the potential to calm users in scenarios where they may experience social anxiety.

The design space for affective haptic sensations is unclear, as researchers typically produce bespoke stimuli then evaluate their affective qualities (e.g., via emotional response). Whilst this gives insight into how people respond to such sensations, this trial and error approach to affective haptic design is not informed by user requirements and preferences. In addition, the effect of different social scenarios on user preferences has not been considered fully, so it is difficult to judge how appropriate or effective affective haptic designs are for different social settings and usage contexts.

We take a user-centred approach in this work and explore which sensations users want to experience and why. We look at the behaviours, affective cues and sensations they would like to experience to help calm them in social settings. By exploring users' needs and wants, we can identify compelling and desirable affective haptic stimuli and can gain valuable insight into how and why these needs might vary across different settings and for different purposes. Our findings can then inform the design of affective haptic experiences.

We report findings from a survey (N=81) that investigated user preferences for calming affective stimuli across a range of social settings. We asked participants to envision themselves in four social situations then suggest haptic or auditory sensations they would find pleasant and calming, to help inform the creation of reassuring haptic cues [33, 51]. We also explored texture and form-factor preferences. Responses showed a wide variety of suggestions, which were then grouped into common themes by the real world experiences they emulated. Our results led to novel affective haptic stimuli designs, informed by user needs and preferences, also giving insight into how these vary based on social settings. Our findings, alongside prior affective haptic work, can inform the design of pleasant multimodal sensations that users want to experience to help calm themselves. Our main contributions include:

- Qualitative analysis of a survey detailing the range of affective stimuli people wish to experience per social scenario;
- Recommendations about how to meet peoples' needs for calming haptics using existing haptic technology.

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# 2 RELATED WORK

## 2.1 Affective Haptic Sensations

Research has investigated how affective haptic sensations can be created and how people respond to them. Conveying and inducing emotion via vibrotactile is still a new research topic within the haptics field, with most work taking place in the past decade and foundational papers still emerging [23]. Emotional responses to vibrotactile and thermotactile stimuli, often measured by valence and arousal (via the Circumplex Model of Affect), have been studied [23, 51, 59, 62]. Abstract vibrotactile stimuli were found to have a wider arousal than valence range, and vibration intensity led to increased arousal [23, 59, 62]; arousal had a negative relationship with valence. Thermotactile stimuli can evoke both positive and negative valence values, with warm or cool stimuli respectively [59]. When combined with vibration, the thermotactile component governs valence while vibrotactile governs arousal [59].

An effective way of evoking an emotional response is triggering the CT afferent receptors [40] within non-glaborous (hairy) skin using slow stroking sensations [32, 36]. These receptors respond strongly to skin deformation and stroking, eliciting a pleasant emotional response. Different setups have been used for stroking, from brushing, to a linear sequence of actuators [13, 26, 43]. This stimulation tends to result in positive valence, peaking at stroking speeds between 1–10cm/s [26, 32, 43] and, similarly to vibration, intensity results in increased arousal and decreased valence [26, 32].

A novel method for creating affective haptic cues is *emotionally resonant haptics*: stimuli that evoke real-world phenomena to elicit the same affective response as its non-digital equivalent. Prior to the use of emotional resonance in affective haptics, relaxing sounds that reminded patients of natural phenomena have lessened pain during medical procedures [2, 14] and improved relaxation in simulated natural environments [45, 57]. Additionally, in a study of a bedside noise generator used as a sleeping aid, the role of emotional resonance was important in the efficacy of the different natural sounds [22]. Social robots like Paro the Seal [58] and The Haptic Creature [61] are modelled to look and feel like animals to increase emotional resonance and help users form an emotional bond with them, and both perform animal-like haptic actions.

Emotional resonance has also been used in affective haptics. The Haptic Remembrance Book utilised pictures, sound and haptics to help elderly users reminisce about past experiences [15]. Macdonald *et al.* [34] converted real-world sounds to vibrations to produce new emotionally resonant haptic stimuli and Shim *et al.* utilised a 3x3 array of vibrotactile motors to craft cues emotionally resonant cues [51], eliciting a wider than typical range of affective responses.

Texture is another important variable of haptic experience [30, 31] but research as an aspect of affective haptics is limited. Prior research has shown that people can associate different emotions with different textures [27]. Etzi *et al.* found that smoother textures tended to be perceived as pleasant and speculated that certain textures could remind participants of "grooming and nurturing stimuli" [17]. Non-glossy textures were preferred in a study by Nagano *et al.* [42], but they note that generalisations were limited in usefulness, as individual preferences are intrinsic to haptic experience. Given this, Simm *et al.* [54] included different textures for users to select, to craft devices more comfortable and personal to them.

Contemporary research has so far focused on presenting haptic stimuli and measuring affective response, providing insight into perception and helping to develop haptic technologies for presenting stimuli. This is typically driven by designers or hardware capabilities; little is known about what affective haptic sensations people *want* to experience, a gap we address in this work so that affective haptic designers can meet users' needs and preferences.

## 2.2 Affective Haptics in Social Contexts

Affective touch and haptics have been used in social contexts in areas such as social robotics [3, 58, 60], mediated touch [1, 26, 44] and wearables [4, 29, 54]. Wearable and holdable devices take advantage of the discreet nature of the haptic modality, avoiding the stigma users may feel using assistive devices around others [52]. Azevedo *et al.* [4] and Zhou *et al.* [63] simulated a heartbeat with vibration to relax stressed users, providing a calm external signal to focus on, rather than the symptoms of anxiety (that may bring on further anxiety). Bonanni *et al.* [9] created a scarf with integrated vibrotactile actuators, to provide pleasant affective touch sensations. Vibrotactile actuators were also integrated into a wearable sleeve by Kelling *et al.* [29], who found that calming haptic patterns lowered users' heart rates, potentially reducing anxiety.

A variety of techniques have been explored to mediate affective touch between people. Research into how emotions are conveyed by touch between individuals [24, 37] has laid a foundation for how haptic technology can mediate such behaviours. Several haptic mediated touch setups have been investigated, including force-feedback [1], vibrotactile [1, 26] and midair haptics [44] devices.

Several social robots have incorporated affective touch into their design. A survey of owners of therapeutic seal robot Paro cited the ability to "touch and hug" Paro, as well as its "tactile texture", as being important in their positive evaluation of the robot [58]. Paro also provides haptic feedback by moving in response to touch, supporting the bond between pet and owner, and Chang *et al.* [10] found that Paro helped promote interpersonal social interactions in care homes when performing the role of a mutual social object. Similarly, The Haptic Creature uses haptic interaction to simulate animal behaviours and communicate its internal emotional state [60]. Likewise, the Haptic Remembrance Book [15] used an affective haptic object to stimulate social interaction, by playing vibrations and audio to remind nursing home residents of past experiences, helping to prompt conversation.

Affective haptic experiences can use many form factors to support users in social scenarios, e.g., as a relaxation aid, touch mediator, or social stimulant. As noted by Bonanni *et al.* [9], the range of user preferences for pleasant haptic sensations is wide and varied, thus a better understanding of *what* sensations users want to experience and *how* they can be achieved will be vital in providing effective personal haptic interventions in future. We contribute an understanding of these preferences and how they can be implemented with existing technology.

## 2.3 Affective Haptics as Emotion Regulation

Calming haptics can act as an emotion regulation tool. Emotion regulation is defined by Gross as how we try to influence *which* emotions we have, *when* we have them, and *how* we experience and express them [20, 21]. Strategies for emotion regulation fall into two broad categories: preemptive antecedent strategies and response-focused strategies [20]. Calming haptics can be used for both. Aforementioned heartbeat-like stimuli can aid emotion regulation: redeploying participant attention [20] from stress or anxiety symptoms, to an external sensation [4, 12], preventing a downward spiral of worsening anxiety symptoms [39, 48].

Emotion regulation techniques other than attention redeployment could be augmented with affective haptics, such as safety behaviours, which are actions taken to reduce the impact of a feared event [8, 39, 49, 56]. Examples include focusing on a smartphone or fidgeting with clothes. People use safety behaviours to try reduce the negative impact of stressful situations, like exposure therapy for the socially anxious, used in front-line therapies like Cognitive Behavioural Therapy (CBT) [18, 53, 55].

The effects of safety behaviours on therapy are divisive, however, as some argue reducing the impact of the feared event weakens the therapy's impact [8, 49], while others argue that safety behaviours can support adherence to difficult therapy [8, 46]. Affective haptic feedback can be calming [4, 12, 51, 64] and augmenting safety behaviours with these stimuli has the potential to improve their ability to reduce stress, while taking advantage of existing behaviours that do not require users to learn new interaction techniques.

## 3 USER STUDY: STIMULI PREFERENCES

### 3.1 Study Aims

We conducted an online survey to elicit suggestions and explore preferences for affective auditory and haptic stimuli for use in social settings. Our aim was to investigate user preferences for calming stimuli and to explore how these varied with intended usage context, with a goal of better understanding the currently unknown affective haptic design space.

We presented four social scenarios and asked participants to imagine themselves in those settings; they were then asked to suggest auditory and haptic stimuli they would find calming in those scenarios. In addition, they also indicated preferences from a pre-selected assortment of stimuli intended to encourage them to consider other ideas. Whilst our focus was on affective haptics, we included audio as these suggestions can effectively derive haptic designs[34], lead to cues with cross-modal correspondence for increased valence [19, 35] and allowed participants to suggest more sensations they have lived experience with while revealing the wider calming experiences they wish to experience.

### 3.2 Survey Procedure

Individuals over 18 with full tactile and audio sensory capabilities were invited to take part in the study, via university mailing lists, posters and social media posts. Participants were not compensated, but were entered into a prize draw for an online retail voucher. Eighty-one people (48F, 29M, 4 Other) with an average age of 38.7 years (SD 14.0) completed the survey.

Participants were asked to imagine themselves in four scenarios, chosen to represent two dimensions: public vs private space, and intimate vs non-intimate relationships: (1) having an important discussion with their partner at home about their relationship (private, intimate); (2) being asked unexpected questions in a job interview (private, not intimate); (3) having a discussion with a friend at a cafe about a serious issue (public, intimate); and (4) sitting in a bar in an unfamiliar social group (public, not intimate).

These scenarios were chosen to represent a mixture of public, private, intimate and non-intimate situations. Familiar settings and relationships aimed to help participants imagine themselves in those scenarios, or recall past experiences, so we could observe how stimuli preferences changed per social situation. For each scenario, we asked "If you could choose to feel any touch sensation or hear any sound to relax you in this scenario, what would you choose?".

After suggesting stimuli through open text responses, we then asked them to choose multiple options from a predefined selection of 18 stimuli that may also be relaxing (listed in Table 3). These were based on suggestions from the research team and those used in prior work on affective stimuli [34]. This question produced further data on which experiences participants want and gave them the option to register interest in stimuli they did not consider.

After this, participants were asked to suggest *textures* they found pleasant, *objects* they fidgeted with when stressed, and *techniques* or *activities* they used to relax after a stressful experience. Texture has had little prior research in this domain, yet is a rich part of the tactile modality and could expand the range of affective haptic experiences for exploration in future work. Understanding what objects users fidget with gives insight into the real haptic experiences already used for relaxing behaviours, while also identifying form factors and fidgeting 'actions' for future affective haptic interfaces. Relaxation techniques would give similar insight into current strategies used by participants and could reveal compelling strategies for augmenting with digital affective haptics.

### 3.3 Qualitative Analysis

All questions had open-ended text responses for participants to suggest their own haptic and auditory stimuli. These were reviewed and pertinent concepts were assigned initial codes. Where appropriate, codes were reused and adapted to establish consistent coding schemes. A pair of researchers both conducted this process independently and created individual coding schemes. They then collaborated to consolidate these into one combined scheme, by collating or distinguishing between codes as appropriate. They then created a set of higher-level codes by bringing related codes together to better represent the themes present in the survey responses.

We used the same process to codify the responses to questions about texture, objects and relaxing behaviours, expanding the set of codes obtained from the social scenario questions. Finally, we also analysed the choice from pre-selected stimuli list by counting their number of occurrences and reflecting on how they fit into the schema that emerged from our analysis of participant suggestions.

### 3.4 Results

Sixty-five codes were identified in the final coding scheme, drawn from 567 responses: i.e., 81 participants × 7 questions (four scenarios plus textures, objects, activities). Fourty of these codes were from responses to the social scenario questions, with an additional 25 identified for the suggested textures, fidgeting objects and relaxing behaviours. An new individual code was assigned if mentioned by several participants, otherwise responses were grouped into a larger code. For example, many participants mentioned fidgeting with objects were mentioned only once, whereas objects mentioned multiple times were assigned a sub-code (e.g. Stress Ball).

Codes were structured to represent the relationships between them. From these, we identified four high level codes that represented different categories of experience:

**Social** Social contact and experiences;
**Natural** Auditory and tactile experiences from nature;
**Human** Experiences with, and from, the human body;
**Artificial** Sensations from man-made objects or experiences.

Note that some codes were shared between two high-level codes. 'Human' and 'Social' shared the 'Human Touch' and 'Human Voice' codes. Similarly, 'Natural' and 'Social' shared the 'Animal' code, which was often (but not always) linked to animals with whom participants had a close relationship (i.e., family pets). Six codes were defined as prominent recurring attributes: 'Background Sound', 'Soft', 'Warm', 'Stroking', 'Repetition', and 'Pressure' (see Table 2). These were not distinct to any one higher level experience, but an attribute of many. For example, 'Soft' is an attribute of many codes including 'Fabrics', 'Animal Touch' and 'Human Touch'.

*3.4.1 Job Interview Scenario.* In this scenario, we asked participants to imagine themselves being asked unexpected questions in a job interview, representing a private and not intimate situation (see Table 1). The largest high level code was 'Artificial' (33), most commonly for sounds like Music (11). Nature experience codes were also prevalent (31 times), most often for 'Animal Sounds' (7; e.g., cat purring as an auditory and haptic sensation), 'Animal Touch' (7; e.g., pets), and 'Water' sounds (13).

Responses showed desire for 'Social' experiences, e.g., with pets ('Animal': 14) or other people ('Human Touch': 11). 'Hand' was the most common Human Touch suggestion, while 'Animal Touch' mentioned stroking and softness, an attribute code which also appeared alongside 'Fabric'. The most prevalent attributes assigned to suggestions in this scenario were 'Background Sound' (25), 'Warm' (9), 'Repetition' (8), 'Stroking' (5), 'Pressure' (5) and 'Soft' (10).

*3.4.2 Bar Scenario.* In this scenario, we asked participants to envision themselves in an unfamiliar social group in a bar, representing a public and not intimate setting (see Table 1). The most frequent high level code was 'Artificial', occurring 42 times, most commonly for 'Music' (25) as many people suggested they would like to hear favourite or familiar music playing in the background. Other 'Artificial' experiences included 'Fidget Objects' (10; e.g., phones, beer mats) and 'Fabric' (3; e.g., clothing). Notably, these sounds and objects are often found in this setting. In contrast, 'Natural' codes were only used 9 times, perhaps because these were inconsistent with this setting or because there were contextually appropriate diegetic stimuli available. 'Social' and 'Human' codes were frequently used (23 and 20 times, respectively). These often represented feelings of physical contact with others, e.g., 'Human Touch' (11) including suggestions of "a hand of my friend on my back" or "a reassuring hand on my shoulder". 'Human Voice' (7) was also common as diegetic background. All of the auditory stimuli suggestions in this scenario shared the attribute of 'Background Sound' (36). Suggestions were typically diegetic sounds, i.e., sounds that could occur naturally in the scenario, like music or nearby conversations.

*3.4.3 Cafe Scenario.* In this scenario, we asked participants to imagine themselves in a conversation with a friend in a cafe about a serious matter, representing a public and intimate situation (see Table 1). 'Social' and 'Human' experiences were again prominent here (25 and 27 times, respectively). These were often coded as 'Human Touch' (15; e.g., 'Hand' and 'Hug') and 'Human Voice' (9), mostly as background conversation (7) but also as the friend's voice in the scenario (2). Background conversation and 'White Noise' were chosen by some to give the comfort of presumed privacy: "low level conversation so it feels like nobody can hear what we are talking about ". Natural experiences were only suggested 10 times.

Artificial experiences were suggested 36 times, commonly the feeling of holding a 'Mug' (11, typically a 'Warm' mug) and hearing 'Music' (9, often specified as "soft" and "relaxing"). Touch interaction with 'Fidget Objects' (6) and 'Fabric' (4) continued to be consistently mentioned across scenarios. The most prevalent attributes assigned to stimuli suggestions in this scenario were 'Background Sound' (19), 'Warm' (16),'Soft' (9), 'Pressure' (6) and 'Stroking' (4).

*3.4.4 Home Scenario.* In this scenario, we asked participants to imagine themselves having a one-to-one conversation at home with a partner about their relationship, a socially intimate and private situation (see Table 1). 'Human' (33) and 'Social' (35) experiences were the most common high level codes in this scenario. The most common code was 'Human Touch' (23), often specifying 'Hand' or 'Skinship'. These interactions were given the 'Warm', 'Soft' and 'Pressure' attributes. 'Animal Touch' was mentioned 7 times, typically specified with the attribute 'Stroking'.

'Natural' experiences (15) appeared primarily as background sound which was least prominent in this scenario, appearing 17 times primarily as 'Music', 'Nature' and 'Machine Sounds' (e.g. "traffic"). Fabrics were mentioned 5 times, with attributes 'Soft' and 'Warm'. 'Fidget Objects' (8) were often vaguely defined without an object ("Something to fidget with") or with a variety of options given, e.g., play dough or stress balls. The most prevalent attributes assigned to suggestions were 'Background Sound' (17), 'Warm' (9), 'Soft' (8) and 'Repetition' (9), 'Pressure' (6) and 'Stroking (4).

*3.4.5 Texture Preferences.* We identified four high level texture preference codes: 'Soft' (45), 'Smooth' (15), 'Fabrics' (44) and 'Hard' (18), each sub-codes, from 81 total responses. There was 32 codes in total. 'Soft' comprised of 'Animal' textures (11), 'Fabrics' (26) and 8 unspecified. 'Smooth' and 'Hard' codes mentioned of natural materials such as wood (11) or stone (12) and 6 mentions each of Artificial materials metal, ceramic and plastic. 'Fabrics' comprised 9 varieties, the most popular being 'Velvet' (13), 'Fur' (12) and 'Bedding' (9). Less common codes included 'Human Skin' (6 mentions), 'Textured/Non-Smooth' (8) and 'Animal' (5). All of these textures could be used to augment different haptic displays, except for mid-air haptic displays which can simulate textures [47].

*3.4.6 Fidgeting Preferences.* We found two high-level codes: 'Own Body' (35) and 'Artificial Objects' (56). Within 'Own Body', responses cited fidgeting with 'Hair' (14), 'Fingers' (9), 'Fingernails' (7) and 'Hands' (5). Prevalent responses in 'Artificial objects' were 'Phone' (25) and 'Pen' (20), others included: 'Paper' (8), 'Fabric' (8), 'Fidget/Stress Toy' (7), 'Jewellery' (6), 'Bottle' (4) and 'Doodling'

**Table 1: Codes defined for social scenario responses. Note that this does not include codes considered to be attributes, i.e., describing the properties of an experience (e.g., warmth, pressure). The structure between high level experiences, their codes and their attributes is illustrated on Fig. 1. *Some Animal codes were classified as both Social and Natural. **Human Touch and Voice were classified as both Social and Human.**

| Code | Interview | Bar | Cafe | Home |
|---|---|---|---|---|
| Artificial | 33 | 42 | 36 | 23 |
| → Artificial Sound | 15 | 27 | 13 | 10 |
| ⟶ Machine Sound | 2 | 1 | 0 | 4 |
| ⟶ Music | 11 | 25 | 9 | 6 |
| ⟶ Rhythmic Beat | 3 | 2 | 1 | 0 |
| ⟶ White Noise | 0 | 1 | 3 | 0 |
| → Fabric | 6 | 3 | 4 | 5 |
| → Fidget Object | 6 | 10 | 6 | 8 |
| ⟶ Phone | 1 | 2 | 1 | 0 |
| ⟶ Ball | 3 | 1 | 0 | 0 |
| → Mug | 4 | 1 | 11 | 0 |
| → Metal | 1 | 1 | 1 | 0 |
| → Chair | 1 | 0 | 1 | 0 |
| | | | | |
| Human | 18 | 20 | 27 | 33 |
| → Breathing | 1 | 0 | 0 | 2 |
| → Heartbeat | 2 | 0 | 2 | 4 |
| → Own Body | 3 | 1 | 2 | 2 |
| ⟶ Hand | 0 | 0 | 2 | 1 |
| ⟶ Arm | 2 | 0 | 0 | 0 |
| → Human Touch ** | 11 | 11 | 15 | 23 |
| ⟶ Hand | 8 | 8 | 11 | 10 |
| ⟶ Hug | 1 | 0 | 4 | 6 |
| ⟶ Partner | 2 | 1 | 0 | 11 |
| ⟶ Shoulders | 1 | 3 | 2 | 1 |
| ⟶ Skinship | 1 | 4 | 9 | 13 |
| → Human Voice ** | 1 | 7 | 9 | 2 |
| ⟶ Conversation | 1 | 6 | 7 | 1 |

| Code | Interview | Bar | Cafe | Home |
|---|---|---|---|---|
| Natural | 31 | 9 | 10 | 15 |
| → Animal * | 14 | 5 | 4 | 12 |
| ⟶ Animal Sounds | 7 | 1 | 0 | 5 |
| ——⟶ Birdsong | 4 | 0 | 0 | 2 |
| ——⟶ Purring | 3 | 1 | 0 | 3 |
| ⟶ Animal Touch | 7 | 4 | 4 | 7 |
| ——⟶ Cat | 6 | 2 | 3 | 6 |
| ——⟶ Dog | 1 | 0 | 2 | 1 |
| → Forest Sounds | 0 | 0 | 2 | 0 |
| → Water | 13 | 3 | 2 | 2 |
| ⟶ Rain | 4 | 1 | 1 | 0 |
| ⟶ Waves | 5 | 1 | 0 | 1 |
| → Wind | 3 | 0 | 1 | 1 |
| | | | | |
| Social | 26 | 23 | 25 | 35 |
| → Animal * | 10 | 5 | 4 | 10 |
| ⟶ Animal Sounds | 3 | 1 | 0 | 3 |
| ——⟶ Purring | 3 | 1 | 0 | 3 |
| ⟶ Animal Touch | 7 | 4 | 4 | 7 |
| ——⟶ Cat | 6 | 2 | 3 | 6 |
| ——⟶ Dog | 1 | 0 | 2 | 1 |
| → Human Touch ** | 11 | 11 | 15 | 23 |
| ⟶ Hand | 8 | 8 | 11 | 10 |
| ⟶ Hug | 1 | 0 | 4 | 6 |
| ⟶ Partner | 2 | 1 | 0 | 11 |
| ⟶ Shoulders | 1 | 3 | 2 | 1 |
| ⟶ Skinship | 1 | 4 | 9 | 13 |
| → Human Voice ** | 1 | 7 | 9 | 2 |
| ⟶ Conversation | 1 | 6 | 7 | 1 |

**Table 2: Number of times attribute codes assigned to different sensations in total across all four social scenarios.**

| **Background Sound** | | **Pressure** | | **Repetition** | | **Soft** | | **Warm** | | **Stroking** | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Music | 51 | Hug | 10 | Heartbeat | 8 | Fabric | 13 | Mug | 19 | Animal Touch | 10 |
| Human Voice | 15 | Hand | 6 | Rhythmic Sound | 7 | Animal Touch | 7 | Animal Touch | 9 | Skinship | 3 |
| Machine Sound | 7 | Back | 5 | Vibration | 3 | Music | 2 | Partner | 9 | Fabric | 1 |
| Waves | 6 | Shoulders | 2 | Ticking | 2 | Human Voice | 1 | Hand | 2 | | |
| Rain | 6 | | | Machine Sound | 1 | Hand | 1 | Fabric | 2 | | |
| Birdsong | 6 | | | Tapping | 1 | | | | | | |
| White Noise | 4 | | | | | | | | | | |
| Ticking | 3 | | | | | | | | | | |
| Forest Sounds | 2 | | | | | | | | | | |

(3). With the exception of 'Paper' and 'Doodling', all could be augmented with haptic to provide pleasant familiar stimuli.

*3.4.7 Relaxation Techniques.* Five high level codes were identified: 'Hobby' (63), 'Exercise (28), 'Social' (15), 'Coping Mechanisms' (16), and 'Food and Drink' (16). While there was a wide variety of hobbies, some codes were prominent: 'Passive Entertainment' such as TV and video streaming (31), 'Music' (21), 'Games' (12), 'Bathing' (11) and 'Reading' (8). Exercises codes was similarly varied, with 'Walk' (13), and 'Yoga' (8) most mentioned. Social relaxation was split between 'Human' (9) with codes like 'Family' (3) and 'Friend' (3), and 'Animal' (7). The three coping mechanisms codes were 'Meditation' (8), 'Breathing Exercises' (6), and 'Mindfulness' (3). Finally 'Food' was mentioned in five responses and 'Drink' in 12, with sub-codes 'Warm' (7), 'Alcohol' (5) and 'Tea' (4).

**Table 3: Eighteen pre-selected stimuli that respondents could indicate preference for, ordered by total selections (n).**

| Stimuli | n | Stimuli | n | Stimuli | n |
|---|---|---|---|---|---|
| Holding Warm Mug | 169 | Slow Breathing | 74 | Footsteps | 12 |
| Rain | 142 | Running Water | 73 | Engine Idling | 11 |
| Cat Purring | 106 | Wind | 64 | Keyboard Clicks | 9 |
| Slow Heartbeat | 97 | Fidgeting w. Object | 55 | Vacuum Cleaner | 6 |
| Skin Stroking | 79 | Muffled Conversation | 49 | Scratching | 5 |
| Crashing Waves | 75 | Brushing | 22 | Hairdryer | 3 |

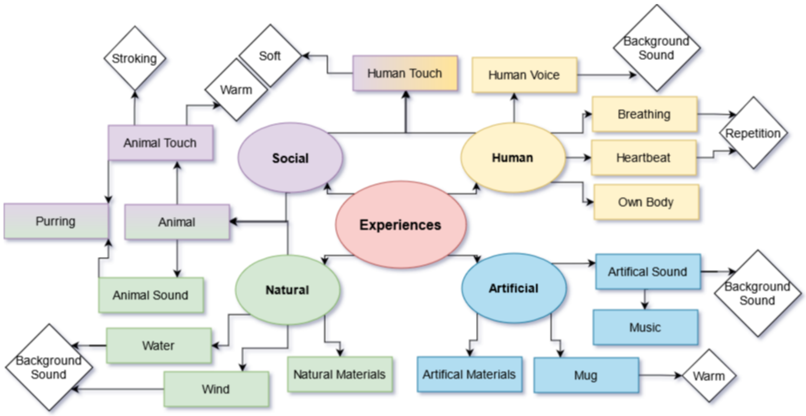

**Figure 1: This figure demonstrates how the data was analysed into a structure of themes, sub-themes and attributes. Shows example codes drawn from all scenarios. Responses were grouped into codes (Rectangles), their attributes (Diamonds), and their higher-level codes (Ovals) indicating wider experiences. Gradients indicate a code shared by high-level codes.**

*3.4.8 Predefined Stimuli Preferences.* After making a suggestion for each scenario participants were given a selection of stimuli hypothesised by the researchers and asked to select any they would enjoy. The total selection count per stimulus can be seen in Table 3. Considering these stimuli alongside the coding scheme, 'Rain', 'Crashing Waves', 'Running Water' and 'Wind' would comprise 'Natural Sensations' and was selected 354 times. 'Slow Heartbeat', 'Slow Breathing' match the 'Own Body' code, selected 171 times. Human and social sensations such as 'Skin Stroking', 'Muffled Conversation', 'Footsteps', 'Scratching' and 'Brushing', had 167 selections. Stimuli grouped as artificial experiences: 'Hairdryer', 'Vacuum Cleaner', 'Keyboard Clicks', 'Engine Idling', 'Holding Warm Mug' and 'Fidgeting w. Object' had 247 selections. Interestingly, natural stimuli were more prevalent during stimuli selection than suggestion. This may indicate that while participants suggested stimuli that were diegetic for each scenario, they considered a wider selection of stimuli pleasant when prompted with more possibilities.

To establish if the stimuli selected were significantly affected by social scenario, Chi-squared tests was conducted for the 9 most selected stimuli, avoiding stimuli with smaller selection counts for which statistical significance would be hard to ascertain. Bonferroni correction indicated an alpha of 0.00056. Three stimuli were significantly more common in the Job Interview than in other scenarios ($p<0.00056$): Running Water ($\chi^2(3) = 15.1$), Crashing Waves ($\chi^2(3) = 22.4$) and Rain ($\chi^2(3) = 14.2$), supporting qualitative findings from the interview scenario where natural stimuli were more prevalent. All three were water related, suggesting water phenomena may be particularly preferred among natural experiences.

Significant effects of gender and age on predefined stimuli selections were found using Chi-squared test with Monte Carlo simulation and ANOVA respectively. For gender, men more often selected ($p<0.00056$) 'Heartbeat' ($\chi^2(3) = 16.2$), while women more often selected ($p<0.00056$) 'Warm Mug' ($\chi^2(3) = 20.1$), and 'Fidgeting' ($\chi^2(3) = 25.0$). Regarding age, participants under the median age of 34 more often selected ($p<0.00056$) 'Warm Mug', 'Skin Stroking', 'Wind', 'Fidgeting' and 'Rain'. Participants 34 and over more often selected ($p<0.00056$) 'Cat Purring', 'Heartbeat' and 'Running Water'.

## 4 DISCUSSION

Our survey explored the range of comforting affective stimuli people suggested in four imagined social settings, as well as preferences for texture, object form factors, and relaxation behaviours. We found that age and gender had an effect on six stimuli, although we did not identify a theme to this small pool of cues. It does serve to further highlight the individual differences that influence preferences for the wide selection of affective stimuli we will now discuss.

### 4.1 Stimuli Suggestions and Preferences

Participants showed a strong bias toward diegetic suggestions in each scenario; e.g., 'Music' was more prominent in the Bar scenario than others, and 'Holding a Warm Mug' for the Cafe scenario. In two instances this was less influential. First, for the job interview, participants suggested and selected natural sensations more often. This may be because there are few diegetic pleasant stimuli present in a job interview, so they instead suggested stimuli they found generically pleasant. Second, when choosing from the pre-selected list, there was less preference for diegetic stimuli, although natural stimuli were statistically less popular in non-job interview scenarios. One participant highlighted specific needs for this scenario: "This scenario would require something discrete", perhaps due to the risk of negative social evaluation in an interview. Given these findings, investigation of which stimuli feel 'appropriate' for different social settings would help define the range of affective sensations that designers should emulate with haptics. Our study has provided insight into these stimuli preferences across four broad scenarios.

Touch sensations codes by users can be broken down into specific sensations that affective haptics could emulate (see section 4.2 for details on how existing haptic technology can emulate different sensations). 'Human Touch' was most prominent in the socially intimate scenarios; Cafe and Home scenario and appeared regularly in others. Within 'Human Touch' are more specific sensations like stroking, pressure, hugs, warmth, heartbeat and tapping. 'Animal Touch' was mentioned across all scenarios and can be broken down into sensations like a furry texture, warmth, cat purring and stroking. It is important to note that emotional connection to the person or pet is also a component of affective social touch, an element social robots emulate to allow these haptic sensations to reach their full potential. Finding a way to implement an emotional connection could enhance these stimuli, for example integrating a virtual character into an app [33] that controls stimuli delivery.

Touch sensations assigned the 'Artificial' code were primarily 'holding a warm mug', and textures like smoothness, hardness, stress toys and fabrics. Sometimes the act of holding was a comfort in of itself: "'Having my hand holding a glass is reassuring, I guess standing with no glass or nothing in my hand in a bar is more stressful". Texture preferences comprised soft, hard, fabric and smooth sensations; specific manifestations varying depending on the desired experience. For example, a 'soft' texture could be an attribute of sensations like soft skin, soft animal touch or a soft fabric. This means designers can use different soft textures to improve the emotional resonance of the sensation they are emulating.

This survey prompted users to make either tactile or audible suggestions for three reasons. Auditory and haptic often have strong cross-modal correspondence and some sounds have been successfully evoked using haptic technology with pleasant results [15, 34]. Auditory suggestions also inform the a wider variety of experiences that users want , allowing for exploration of related haptic sensations. For example, a user calmed by the hearing rain may also be calmed if a haptic stimuli evokes the feeling of raindrops.

Natural experiences were primarily suggested as background sounds, such as the sounds of crashing waves, rain, birdsong and wind. The Cafe and Bar scenarios prompted social atmospheric background noise, like muffled conversation or laughter. Artificial sound experiences varied: in Bar and Cafe scenarios background music was suggested often, but at Home familiar sounds of household appliances, traffic or TV sounds were mentioned. 'Music' was one of the largest codes and suggestions took one of three forms; specific genres like Jazz, Classical and Rock, non-specific(e.g. "Good music", "Background music") or music described as having a"soft slow beat", or rhythmic pulsing. The third category provides the best opportunity for haptic emulation as the majority of the song could be present via vibrotactile without losing detail found in higher frequencies common in other genres.

Knowing participants chose sensations reminiscent of pleasant experiences, such as a walk in nature, or feeling comfortable at home, allows designers to purposely evoke these experiences when creating stimuli. Additionally this survey provides future researchers with a user-focused empirical justification for the affective stimuli they choose to create and test, while reinforcing the sheer breadth of possible preferences possible across different individuals and situations. While there is likely no one stimuli per scenario that most users find calming or pleasant, there are stimuli that each individual would like to experience per scenario and a comprehensive library of haptic cues stands the best chance of enabling a calming haptic display for the majority of users.

## 4.2 Implemented User Suggestions

Using this knowledge of user preferences alongside prior research, we can recommend how to emulate these calming sensations using affective haptic technology in real-world scenarios.

**Human and Social Experiences**

Simulating affective human touch has been the subject of significant mediated touch research and been implemented in different ways [26, 41, 44]. Our participants suggested two main forms of hand interaction: stroking touch from a moving hand and stationary touch such as holding hands or a hand on the shoulder. Stroking sensations have been simulated using haptics by triggering CT afferents using setups including an array of vibrotactile actuators [26, 43], voice coils [13], rotating surfaces [50] or a motorised brush [32]. These methods could more directly replicate stroking from specifically a human hand along with the addition of a thermal modality or a soft skin-like texture.

Simulating a resting human hand is more difficult without any distinct motion, but the use of warmth, texture and pressure provided by actuators to press against the user's skin [51] are possibilities. Obrist *et al.* asked users to define emotionally meaningful patterns which were then delivered to themselves or others using mid-air haptics [44]. This is also a form of affective touch people can apply to themselves and was suggested several times identified by the code 'Own Body'. An embrace or hug is an affective touch over a large portion of the recipient's body and so can be hard to simulate in a discrete or convenient way. Mueller *et al.* explored using an inflatable jacket to provide a sense of pressure around the body [41], but prototype limitations such as noise undermined the device. It is possible that trialling a higher fidelity prototype without these issues could improve the viability of this simulation. The addition of a thermotactile element to provide warmth to the 'hug' may also be appropriate as we identified the 'Warm' attribute across many user suggestions for hugs.

The other prominent social code was 'Animal Touch', either with a cat, dog, or unspecified. Its common attributes codes were 'Warm', 'Soft' and 'Stroking'. Animal touch interaction has been simulated using social robots such as Paro the Seal [58] and The Haptic Creature [60] which implemented furry textures, breathing, vocal responses and responsive body movement. The addition of heat could further enhance the illusion. Many participants mentioned stroking alongside animal touch so a CT afferent array like those discussed prior with animal-like texture could produce a similar experience. Purring was a recurring code, and can be effectively implemented as using a simple vibrotactile actuator [34].

Our respondents showed preferences for other human experiences: feeling a heartbeat and feeling/hearing human breathing. Heartbeats have been successfully emulated using holdable and wearable haptic devices [4, 34, 51, 64] using vibrotactile actuators, with calming results. Several have attempted haptic stimuli reminiscent of breathing: recordings of breathing have been converted into vibrotactile stimuli [34] and specific patterns designed to evoke breathing were developed [38, 51]. Participants found Shim *et al.*'s implementation in particular [51] to be calming and pleasant.

**Natural Experiences**

Natural experience codes were primarily background sound, although some phenomena like water and wind could be felt as well. 'Water' stimuli were mentioned 18 times and sometimes specified as 'Rain' or 'Waves'. For Rain, Shim *et al.* [51] and Israr *et al.* [28] both successfully used a vibrotactile array to simulate variable intensity raindrops landing sporadically. Barreiro *et al.* produced a detailed fluid interaction simulation using a ultrasound haptics array, although emotional response was not measured [6]. Affective response to vibrotactile stimulus generated from the sound of waves have been investigated but participants could not recognise it [34]. Generally, simulating water stimuli should use technology that can present the non-uniform movement associated with many forms of water, such as rain, waves or a stream, perhaps using arrays of haptic actuators that display moving patterns [5, 6, 13, 26, 51].

The other natural phenomena suggested were wind and birdsong. Mid-air ultrasound haptic arrays provide a wind-like experience whose intensities and patterns can be precisely controlled [47]. Birdsong, however, has not seen an effective haptic implementation. Made up entirely of treble frequencies, it cannot easily be represented via vibrotactile. For this, and other difficult phenomena, a solution may be to develop haptic 'words' that represent the phenomena using participatory design [5, 7].

**Artificial Experiences**

The largest code identified was 'Artificial Sound', made up of two primary sub-codes: 'Music' and 'Machine Sound'. Both contain a wide variety of specific phenomena, as music can take many forms and mechanical/technological sounds vary depending on the object. For music, the feasibility of haptic emulation depends on the suitability of the genre. Across all social scenarios binaural beats was suggested, a genre of soft, repetitive bass pulses, suitable for vibrotactile emulation. Similar external rhythmic haptic beats have been found calming in prior research [4] although not specifically with different music tracks. The ability to evoke music may depend on how much of the recognisable rhythm and melody occurs in appropriate frequency ranges (10-500Hz [11]) and the users' familiarity with the song. The majority of suggestions for music were for scenarios where it would be diegetic and so a haptic alternative is less valuable as the original sensations may be used instead.

A variety of mechanical and technological sounds were suggested, each often only suggested once. Many can be grouped as engine sounds, such as traffic, or electric hums from household appliances. These sounds could be displayed via vibrotactile stimuli using rougher, lower frequencies or smoother, higher frequencies, respectively. Fabrics were prevalent and can augment haptic interfaces to add texture, as used in social robots and haptic displays [25, 58]. Adding texture to affective haptic stimuli may prove important in crafting holistic sensations evocative of the experiences users want. A warm mug was commonly suggested, particularly in diegetic scenarios like the Cafe and at home, and can be pleasantly emulated using thermotactile actuators[59] and smooth textures.

**Applying Affective Haptics to Real World Situations**

Many haptics technologies discussed above can be used in social scenarios, providing discreet calming sensations. Vibrotactile actuators are most practical, already integrated into many devices, like smartphones and wearables, and can be experienced in most situations. Thermotactile technologies are less practical as devices like the Peltier [59] feature bulky heat-sinks and significant power requirements, but can augment larger objects, like a chair or a steering wheel [16]. Haptic arrays can display more complex patterns but require larger displays which better suits mounting inside larger objects or clothes. For example, Huisman *et al.*'s haptic array simulates stroking and is mounted around the forearm [26] and could be integrated into clothing sleeves to allow for mobile use. Virtual reality or video game controllers are suitable platforms for a haptic arrays as consistent contact with the hand is possible, but their use cases are limited. Social robots already effectively emulate animal touch but their size and potential stigma around their use [52] can make them impractical for many situations, although they are already used in care home scenarios [58].

## 5 CONCLUSION

This paper presented a novel investigation into user preferences for affective haptic sensations in four distinct social scenarios. Participants were asked to provide suggestions for auditory and tactile stimuli they would find pleasant during four distinct social scenarios, as well as preferences for texture, form factor and relaxation techniques. Qualitative analysis was used to produce a set of codes that describe these preferences and the high-level experiences they are related to. This analysis was used recommend affective haptic designers should seek to simulate and expose the need for a comprehensive selection of haptic stimuli to cater to the breath of individual preferences. Our findings also provide recommendations on how texture preferences can enhance the emulation of different sensations. Finally, user preferences were considered alongside prior research to inform recommendations on how to emulate user-suggested sensations with existing haptic technologies.

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