Tailoring Interactions: Exploring the Opportune Moment for Remote Computer-mediated Interactions with Home-alone Dogs

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ABSTRACT

We argue for research on identifying opportune moments for remote computer-mediated interactions with home-alone dogs. We analyze the behavior of home-alone pet dogs to find specific situations where positive interaction between the dog and toys is more likely and when the interaction might induce more stress. We highlight the importance of considering the timing of remote interactions with pet dogs and the potential benefits it brings to the effectiveness of the interaction, leading to greater satisfaction and engagement for both the pet and the pet owner.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; *Ubiquitous and mobile computing*.

KEYWORDS

Interruptibility, Computer-mediated Human-animal Interaction

ACM Reference Format:
Yewon Kim, Taesik Gong, and Sung-Ju Lee. 2023. Tailoring Interactions: Exploring the Opportune Moment for Remote Computer-mediated Interactions with Home-alone Dogs. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems (CHI EA '23), April 23–28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3544549.3585757

1 INTRODUCTION

Dog owners often leave their dogs at home for many hours due to busy schedules, leading to stressful situations for both the dogs and owners. Isolation is one of the main stressors for dogs [37] and could result in lower levels of physical and vocal activities [22, 48] and anxiety-related behaviors such as chewing, digging, and destruction [42, 45]. Dog owners feel guilty [21] and lonely [23] from leaving their pets alone at home. While pet owners try to comfort home-alone dogs by giving them treats or leaving the radio on, they also feel a strong need to ensure the physical and mental well-being of the dogs by monitoring their status and remotely interacting with the dog [28].

The owners' desire to keep their home-alone dogs healthy and entertained has stimulated a line of research on human-animal remote interaction technologies in both Human-Computer Interaction (HCI) and Animal-Computer Interaction (ACI) fields, such as video-based monitoring and communication systems [16, 38] and smart pet toys for playful experience [11, 26, 53]. While these systems allow individuals to connect with their pets remotely, they are designed primarily for the convenience of pet owners and fail to consider the context of the interaction. Contextless activation of IoT devices could be an *unwanted notification* to the animals, e.g., sound stimuli or sudden movement of devices could worsen stress levels when the dog is sleeping [43].

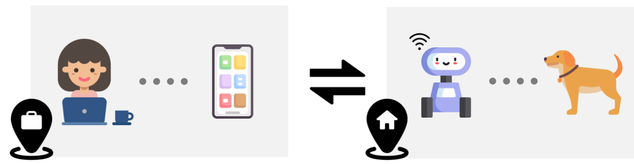


Figure 1: Overview of computer-mediated remote human-animal interaction. Remote interactions operate in IoT environments where the devices for pets are connected to the Internet, and human users remotely control them over mobile applications.

We present a preliminary study that explores the opportune contexts of pet dogs in which remote human-dog interactions are likely to happen. Our findings indicate that there could be specific situations where dogs respond positively to the interaction. Furthermore, we discuss the importance of considering the timing of human-dog remote interactions and the potential benefits it brings to the effectiveness of remote human-dog interaction. We aim to bring attention to the importance of identifying opportune moments in context-aware remote human-animal interaction and pave the way for effective and engaging interactions between humans and animals.

2 BACKGROUND

2.1 Computer-mediated Remote Interaction Systems for Home-alone Pets

To address the needs of pet owners with home-alone pets, various computer-mediated remote interaction systems have been developed. Figure 1 illustrates existing remote interaction technologies operating in IoT environments. Pet cameras are the primary medium of monitoring and communication, as they allow owners to remotely observe the pet's status and initiate desired interactions such as talking to the pets, tossing treats, and controlling laser pointers [9, 16, 33, 38]. Some utilize video conferencing tools for communication between the owner and the pet [12, 41]. Others

CHI EA '23, April 23–28, 2023, Hamburg, Germany

ACM ISBN 978-1-4503-9422-2/23/04.
https://doi.org/10.1145/3544549.3585757

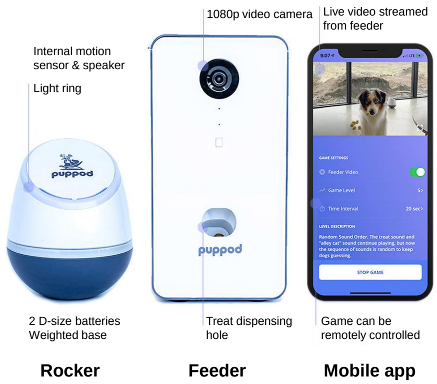
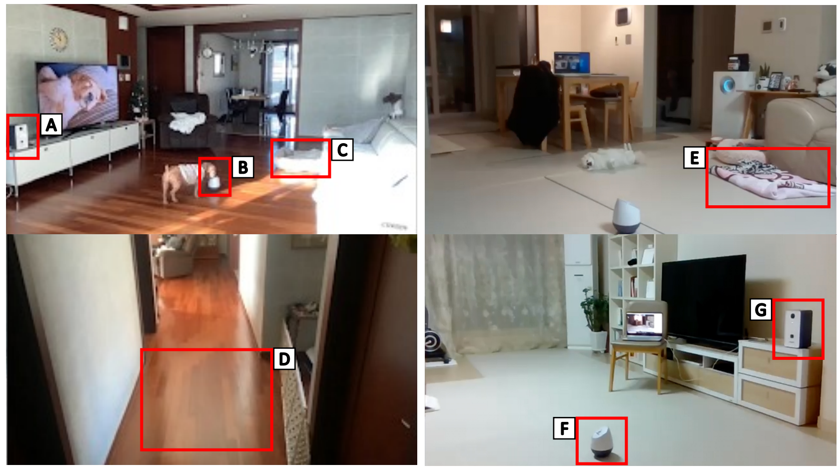


Figure 2: Smart toy used in the study. PupPod consists of Rocker, Feeder, and mobile application, where Rocker serves as the interactive component, Feeder as a reward dispenser, and the mobile application as a remote controller.



(a) Data collection environment of S1 **(b) Data collection environment of S2**

Figure 3: Configuration of the data collection environment. Rocker (B, F) is placed in the living room, and Feeder (A, G) is near Rocker. Video cameras were installed at multiple locations, including the dog's primary resting place (C, D, E), as well as where the Rocker and Feeder were located.

attempted to entertain home-alone pets by designing tangible interfaces where pet owners can remotely control the devices such as moving robots and ball throwers [26, 52, 53]. Some provide puzzle-solving games for home-alone dogs that can be remotely activated by dog owners [6, 36, 40]. It was also shown that a game that utilizes a device where dogs get treats by pressing a sound-emitting button could lessen the stress levels of home-alone dogs [11].

2.2 Interruptibility and Opportune Moments for Remote Human-pet Interactions

In human research, interruptibility refers to the degree to which a user is responsive to a system's attempts to interact with them, and an opportune moment is a time when the interference of the user's current task is minimal [1]. In context of animals, we adopt a similar definition and define interruptibility as an animal's responsiveness to the system's attempts to interact with it, opportune moments as a time when the animal is likely to engage with the device, and inopportune moments as interactions that result in negative consequences, such as an increase in stress signs.

Various interruption methods have been proposed to initiate remote human-pet interactions, yet few consider pets' interruptibility. Interruptions can be initiated without context; a user can randomly trigger [36] or schedule [6, 11, 40, 52] interactions. While this type of simple interaction requires little user effort, it is impossible to guarantee that the timing of the interruptions is optimal as the interruptions are made without any context. An alternative approach is to initiate context-aware interactions by manually observing the pet, e.g., via camera, and trigger interactions [9, 16, 33, 34, 38]. However, it is limited by the fact that it requires a great deal of user effort, which is infeasible in many practical scenarios. Researchers have proposed a context-aware interaction system that allows the user and the system to interact based on the context. For example, Pawsabilities [26] notifies the user to trigger ball throwing only when the dog sits on its bed. Feline Fun Park [53] automatically activates the device when the cat approaches the system. Although context-based, these systems rely heavily on naive assumptions about opportune contexts for interaction. A recent work [51] investigated home-alone dogs' perceptions toward disembodied stimuli but focused on the stimuli type, not the interruptible context of the dog. We aim to understand the complex and nuanced factors that contribute to opportune moments for successful interactions with home-alone dogs.

3 METHOD

To understand opportune contexts of interactions for home-alone dogs, we conducted an explorative study with two pet dogs. To ensure that the experiment results were reflective of the dogs' natural environment, the study was conducted in their homes. Our study was approved by our Institutional Review Board (IRB) and Institutional Animal Care and Use Committee (IACUC).

3.1 Data Collection

3.1.1 Participants. We recruited two pet dogs whose owners reported that they left their dogs alone at home for more than two hours at least once a week. One subject (S1) was a six-year-old Miniature Poodle (intact female, 8.9 kg), and the other (S2) was a five-year-old Pomeranian (spayed female, 3.6kg). The subjects were recruited through personal networks using the snowball sampling method.

3.1.2 Interaction Device. We used a commercially available puzzle-solving pet toy, PupPod [36], in the experiment. The toy consists of three components: Rocker, Feeder, and mobile application (Figure 2). Rocker serves as an interactive component that emits sounds and

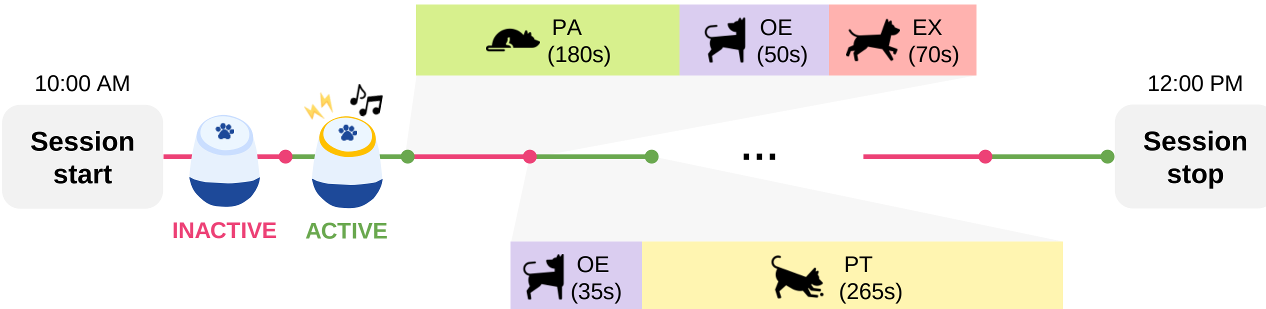


Figure 4: An overview of the experiment procedure. Refer to Table 1 for the detailed interpretation of the behavior categories.

lights in order to attract the dog's attention and engage the dog in a puzzle game. Upon solving the puzzle, Feeder dispenses treats as a reward. Owners can control the interaction remotely via a mobile application, which allows them to set game levels and schedule games. In our experiment, we selected the easiest level where the puzzle is to touch the device when the sound is emitted in order to ensure that dogs know how to interact with the toy. We selected PupPod to minimize any potential disturbance or alerting effect on home-alone dogs as PupPod emits only sound and light, which are less intrusive than the movements of other interactive devices. A one-week adaptation period was given to the participants prior to the experiment in order to ensure they were familiar with the toy and to prevent the novelty effect.

3.1.3 Data Collection Environment. We collected data from the participant's domestic environments where they reside. As shown in Figure 3, we placed the Rocker in the living room and the Feeder near the Rocker where the pet dogs cannot reach. During the experiment, the owners were asked to record videos of their dogs whenever they left home for more than 120 minutes. Video cameras were installed in multiple places to cover both the dog's primary resting place and the place where the PupPod was installed. The owners were asked to start the recording and contact the authors right before their departure from home. Data collection was done under their normal life routines. When the owner left home, the researcher remotely started the experiment protocol for 120 minutes as described in Figure 4.

In the experiment session, PupPod was activated and deactivated every five minutes. Upon activation, PupPod emitted a bell-ringing activation sound, followed by whistles every 10 seconds. When the dog successfully touched the toy after the whistle, treats were dispensed as rewards. After five minutes, PupPod emitted a beeping deactivation sound and was deactivated for five minutes, indicating that no further stimuli were emitted until the next activation period. As a result, we collected 10 hours of audio and video data, which consists of four experiment sessions for S1 (eight hours) and one experiment session for S2 (two hours).

3.2 Data Preparation

The recordings were labeled and analyzed by the authors. When labeling the dog's activity, we used a focal animal continuous recording method [2] with the BORIS event logging software [8]. We followed the behavior categories proposed by previous studies [30, 31, 42, 44], which are summarized in Table 1. Specifically, behaviors were categorized into states and events, with states recorded as duration and events as frequency.

3.3 Data Interpretation

Unlike previous interruptibility research [4, 15, 19] that uses the experience sampling method (ESM), explicitly asking questions and collecting responses from animals is impossible. We instead infer the interruptibility of the pet dogs via behavior analysis and the dog's engagement towards the activated toy.

3.3.1 Interpretation of Behavior Categories. Previous animal behavior research showed the possibility of classifying the behavior categories as stressful conditions and non-stressful conditions. Exploration, proximity to toys, and passive behavior could be interpreted as relaxed and non-defensive behavior [30, 46]. On the other hand, fear and anxiety are known to cause defensive, attentive, or aggressive behaviors including vocalization, orientation to the environment, scratching, and shaking [27, 30]. Dogs are also known to show self-calming behavior such as yawning and lip licking when stressed [3]. Lastly, proximity to the door indicates that the dog is searching for the owner, showing insecure attachment behavior to the owner [39, 50]. Identified behavior categories are marked by color in Table 1.

3.3.2 Engagement Score. Along with the behavioral analysis, We compute how much the dog was engaged in the game during the 5-minute long toy activation session. We define the engagement score as follows:

$$\textit{Engagement score (ES)} = \frac{\text{\# successful interactions}}{\text{\# possible maximum interactions}},$$

where "# successful interactions" refers to the number of successful gameplay rounds that a dog earned treats and "# possible maximum interactions" is the maximum number of rounds that a dog can play in a 5-minute activation session. Since the toy emitted sound every 10 seconds, we set the "# possible maximum interactions" to $\frac{300\text{sec}}{10\text{sec/round}}$ = 30 rounds. Therefore, the engagement score (ES) ranges from 0 to 1 (0-100%) and the higher the score, the more opportune the context is.

Table 1: Behavior categories used in our study. Categories with red color denotes that the dog could be in a stressful condition (anxious; defensive), and green color indicates a non-stressful condition (relaxed; non-defensive; playful).

Category code	Behavioral category	Definition
Duration (State)		
VO	Vocalization	Barking, whining, or howling.
OE	Oriented to the environment	Sitting, standing or lying down (the head does not rest on the ground) with an obvious orientation toward the physical or social environment, including sniffing, close visual inspection, distant visual inspection.
PD	Proximity to door	Resting, still, active within 1 m of the door, with head oriented to the door.
PA	Passive behavior	Lying down with the head on the ground without any obvious orientation toward the physical or social environment. (sleeping or resting)
PT	Proximity to toy	Still or active within 0.3 m of the toy (PupPod), with the head oriented to the toy, including interactive and playful behaviors toward the toy.
EX	Exploration	Motor activity directed toward physical aspects of the environment, including sniffing and gentle oral examination such as licking.
Frequency (Event)		
YA	Yawning	Yawning
LL	Lip licking	Part of the tongue is shown and moved along the upper lip
SC	Scratching	Scratching of the body, neck, or head with a hind leg
SH	Shaking	Shaking head and body

4 RESULTS

After one week of the data collection period, a total of 10 hours of audio and video data were collected: four experiment sessions for S1 (eight hours) and one experiment session for S2 (two hours). We excluded three pairs of toy inactive/active intervals in S1 (= 30 minutes), in which the dog was unseen for a long time or the toy malfunctioned and did not dispense the treats after a successful interaction. As a result, we analyzed 45 pairs of toy inactive/active intervals in S1 and 12 pairs in S2.

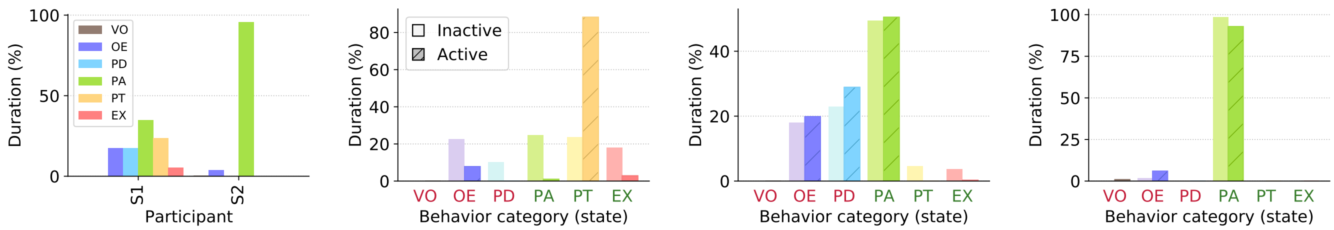
4.1 Behavior analysis

In order to evaluate whether dogs behaved differently when the toy was activated as opposed to when it was inactivated, we compared the duration and frequency of behavior categories depending on the activation status of the toy (activated/inactivated). Based on the total length of each 5-minute inactive/active interval, durations of states were calculated as a percentage of total observation time, and the frequency of events was expressed as counts per each interval.

4.1.1 Duration of states. Figure 5a shows the overall proportional durations of states (VO, OE, PD, PA, PT, EX in Table 1) for S1 and S2. Both dogs spent most of their time resting and sleeping (PA; 34.97% in S1 and 95.68% in S2). While S1 showed diverse behaviors, including interacting with the toy (PT; 23.87%), S2 did not interact with the toy and exhibited passive behavior most of the time and occasionally anxiety-related behaviors (OE; 3.82%, VO; 0.50%).

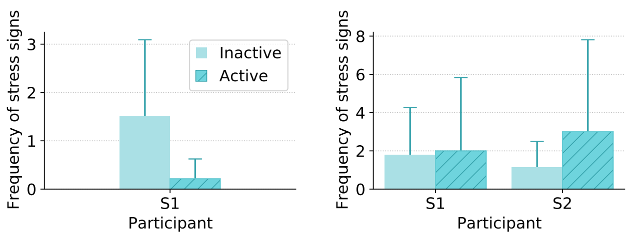
In order to examine whether there is an (in)opportune moment for interaction, we categorized the data into two: when the dog was *interruptible* and *uninterruptible*, and compared the durations of behaviors before and after the toy activation. We assumed that if the dog interacted with the toy at least once within a single activation interval, the dog was interruptible. The results are shown in Figures 5b and 5d. Note that we only observed an uninterruptible case for S2, as S2 did not interact with the toy throughout the entire experiment. When S1 was interruptible (Figure 5b), it is evident that S1 spent a significant amount of time interacting with the toy (PT), and durations for the other behaviors decreased accordingly. In contrast, when S1 and S2 were uninterruptible (Figures 5c and 5d), we could observe a trend in which durations of stress-related behaviors (VO, OE, PD) increased. Similarly, non-stress behaviors (PA, PT, EX) slightly decreased except for the passive behavior (PA) in S1. This suggests that while triggering interactions at opportune moments increases playful behaviors (and thus well-being) of home-alone dogs, initiating at inopportune moments may cause adverse effects on the dog, such as increased stress levels.

4.1.2 Frequency of events. We analyze the frequency of events (YA, LL, SC, SH in Table 1) before and after the toy activation. We grouped all events together as a single category of "stress signs," since events other than lip licking (LL) were rarely observed in the data, making it difficult to analyze them separately. Figure 6 shows the results. Similar to Section 4.1.1, only the analysis of the uninterruptible case is reported for S2. When S1 was interruptible (Figure 6a), the frequency of stress signs significantly decreased, implying that the dog was enjoying the playful experience. In contrast, when dogs were uninterruptible (Figure 6b), the frequency of stress signs during the activation intervals was higher than that of inactivation intervals, suggesting that the inopportune timing of interactions might lead to increased stress levels for dogs. These findings align with those in Section 4.1.1, highlighting the importance of timely interactions in shaping a dog's well-being.



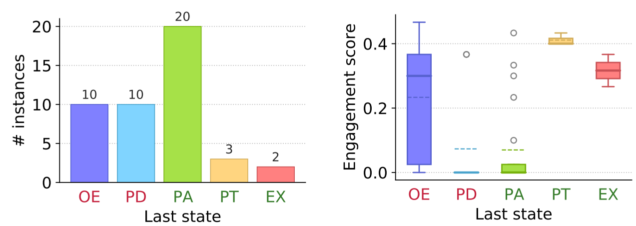
(a) **Overall statistics.** (b) **Interruptible (S1).** (c) **Uninterruptible (S1).** (d) **Uninterruptible (S2).**

Figure 5: Proportional duration of behaviors in S1 and S2. Stress behaviors are colored red and non-stress behaviors as green.



(a) **Interruptible.** (b) **Uninterruptible.**

Figure 6: Mean frequency of stress signs before/after the toy activation, depending on interruptibility.



(a) **Statistics of last states.** (b) **Engagement score of states.**

Figure 7: Engagement score given the dog's states right before each toy activation session. Stress behaviors are colored red and non-stress behaviors as green.

4.2 Engagement Score

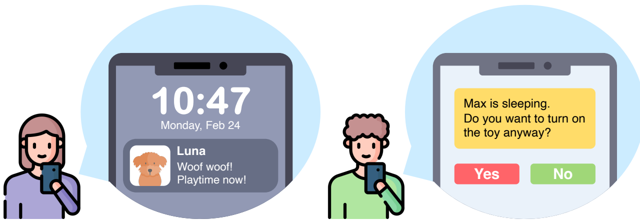
In order to explore the opportune contexts for triggering interactions, we analyzed the relationship between the engagement score (ES) and the dog's state right before each toy activation. For instance, in Figure 4, the last state would be exploration (EX). Figure 7 shows the results. The highest ES was 0.47 in our experiment; although the maximum value of ES is 1, we consider it as significantly high, as it took on average 20 seconds to solve the puzzle and eat the treats for S1 (therefore, 300/20=15 is a practical maximum ES value). S1 highly engaged with the toy when it was in proximity to the toy (PT) and exploring the environment (EX), while it exhibited low engagement scores when it was showing passive behavior (PA) or in proximity to door (PD). When it was oriented to the environment (OE), it had varying engagement scores. The result from S2 aligns with S1 in that it spent most of its time resting and sleeping (PA) and did not respond to the toy. Our findings indicate that certain behaviors might be more conducive to engagement with the interactive device. For instance, our data shows that dogs are more interruptible when they are active (PT, EX) compared to when the dogs are passive (PA, PD). A considerable number of anomalies and varying ES in PA and ES suggest that other contextual factors, such as more fine-grained psychological states of dogs (e.g., tired vs. boredom), might play a significant role in determining opportune moments for interaction.

5 DISCUSSION AND FUTURE WORK

We discuss the potential benefits of considering interruptibility in home-alone dogs and possible applications that could improve computer-mediated human-animal interactions. Specifically, we discuss context-aware interaction systems (Section 5.1), personalized interactions (Section 5.2), and automated playful systems for home-alone dogs (Section 5.3). We also suggest future directions for scaling up the study, including a deeper investigation of contextual factors (Section 5.4) and stimuli activation methods (Section 5.5) in the study design.

5.1 Enhancing Emotional Bond between Human and Pet via Context-aware Interactions

Our study implies that the traditional forms of computer-mediated interactions between humans and pets have been primarily unidirectional and human-centered, as previous works in ACI also noted [24, 25]. By identifying opportune moments for interaction and developing context-aware applications, we can shift towards bidirectional interactions that take into account the pet's context. As a demonstration of this approach, we present example designs of bidirectional interaction systems (Figure 8). One such system is a context-aware notification system (Figure 8a) that initiates interactions by notifying the pet owner when the dog is in an *interruptible* state. Motivated by the previous work on humans [5], another approach is a sender-controlled interaction system (Figure 8b), in which the pet owners can decide whether to initiate remote interactions based on the current status of their pets. These approaches allow for the initiation of remote interactions at the appropriate time, leading to more successful and rewarding interactions. Additionally, by taking into account the pet's interruptibility, we can avoid frustrating interactions in which the pet refuses to engage. These context-aware interactions can lead to more satisfying experiences for both the pet and the owner, ultimately leading to an enhanced emotional bond.



(a) Context-aware notification. **(b) Sender-controlled interaction.**

Figure 8: Illustration of potential context-aware bidirectional interaction systems.

5.2 Personalizing Interactions

The analysis of the participants in our study revealed notable differences in the behaviors exhibited during the experimental session. This variability can be attributed to individual preferences and personalities of the pets [49], with opportune and inopportune moments potentially serving as personalization factors. These findings align with previous studies on dog behavior, which have also noted a high degree of variability in terms of engagement with devices [7]. In addition, it is important to consider the role of the interaction medium in determining a pet's engagement. In this study, we utilized a treat-tossing puzzle toy with sound stimuli; however, it is possible that different stimuli, such as movement or visual cues, and different rewards, e.g., ball throwing, may be more engaging for certain dogs [51]. Therefore, taking into account the individual preferences and characteristics of the pet, as well as the nature of the interaction medium, may be essential for achieving personalized remote human-pet interactions.

5.3 Automated Playground for Home-alone Dogs

In addition to improving human-pet interaction, identifying these opportune and inopportune moments can be beneficial in the design and development of automated pet-computer interaction systems [34, 35]. By leveraging the knowledge of opportune and inopportune moments for a pet, automated systems can be built and personalized to provide an "automated playground tailored for the pet." Such systems could improve its well-being and keep it engaged and active even when alone. This approach could also help to alleviate the negative feelings pet owners may experience when leaving their pet alone [21], as they are aware that their pet is entertained and engaged. This can ultimately lead to a natural and seamless animal-computer interaction, resulting in greater satisfaction and engagement for both the pet and the human.

5.4 Contextual Factors Determining Opportune Moments

In our study, we explored the opportune and inopportune moments for remote computer-mediated human-dog interactions through behavior analysis of video data. To further investigate the impact of timing on human-dog interactions, it would be beneficial to consider a wider range of contextual factors. One such factor could be physiological data, such as heart rate [10] and body temperature [29]. By measuring these physiological responses, we could gain a deeper understanding of the dog's state and how it is affected by interaction timing. In addition, using inertial measurement unit (IMU) data [14] to detect fine-grained activity levels could provide more detailed insight into the dog's engagement during interactions. Another avenue for future research could be the analysis of tail position as an indicator of emotional state. The tail position has been shown to be a reliable indicator of dog emotions [20, 47], and analyzing the tail position in conjunction with behavior analysis could provide a more comprehensive understanding of the dog's emotional state during interactions. By considering a wider range of contextual factors with larger sample sizes, we can further improve our understanding of the factors that shape successful remote human-dog interactions.

5.5 Effects of Activation Stimuli on Dogs

In our experimental setup where PupPod was activated and deactivated every five minutes (Section 3.1.3), the dogs were subjected to noise during the activation periods even when they did not engage with the toy. Although our goal was to imitate real-life situations where owners turn on the toy without considering their pets' contexts, we acknowledge there could be potential concerns regarding the frequent and prolonged exposure of dogs to the activation stimuli. Previous studies indicated that dogs experience stress in response to noises [13, 18], highlighting the importance of a comprehensive understanding of how stimuli exposure affects dogs' behavior and well-being. To address these concerns, future studies could explore the effects of different durations and frequencies of toy activation sessions, or consider randomizing the activation timing of the stimuli, following the previous studies on measuring human interruptibility [15, 17, 32]. With deeper understanding of the effects of stimuli exposure on dogs, we can design experiment procedures that prioritize their well-being while also accurately measuring their engagement during remote human-dog interactions.

6 CONCLUSION

In this preliminary study, we analyzed the behaviors of two home-alone dogs to understand opportune and inopportune moments for remote human-pet interactions. Results show a potential for these moments to exist in computer-mediated interactions, as engagement score was high in certain behavior categories such as proximity to toy and exploration, and stressed-related behaviors increased when the toy was activated for uninterruptable dogs. These findings suggest that the timing of interaction may play a significant role in the effectiveness of computer-mediated dog-human interaction, and further research is needed to identify the most opportune moments for successful interactions.

ACKNOWLEDGMENTS

This work was supported in part by the Institute of Information & Communications Technology Planning & Evaluation (IITP) grant funded by the Korea government (MSIT) (No. 2022-0-00064, Development of Human Digital Twin Technologies for Prediction and Management of Emotion Workers' Mental Health Risks).

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